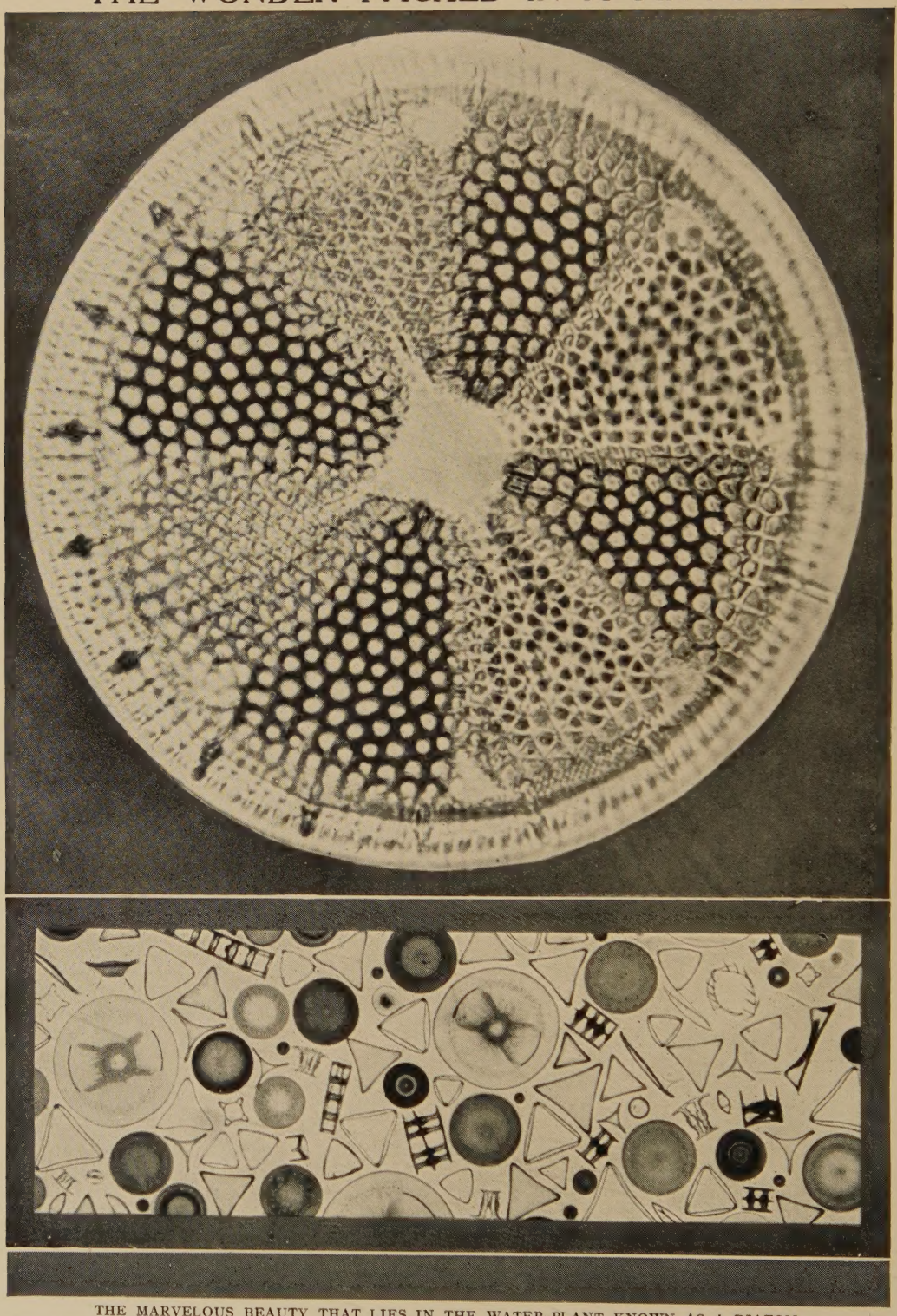
The Book of
POPULAR SCIENCE

The Wonders of Modern Discovery
The Triumphs of Inventive Genius
The Story of all Created Things and
the World They Live In

VOLUME VIII

THE WONDER PACKED IN A PIN-POINT



THE MARVELOUS BEAUTY THAT LIES IN THE WATER-PLANT KNOWN AS A DIATOM

The diatom is suggested in its natural size by the pin-points at the bottom; above is a group photographed under the microscope; and at the top is a single diatom magnified to a million times its proper size, revealing the almost incredible wonder that nature can pack into a speck often invisible to the eye.

The Book of
POPULAR SCIENCE

The Wonders of Modern Discovery
The Triumphs of Inventive Genius
The Story of all Created Things and
the World They Live In

EDITED by a group of distinguished scientists including members of the faculties of the Massachusetts Institute of Technology, Cornell, Harvard and Leland Stanford Universities, The Universities of Iowa, Michigan, Rochester, Tokyo, Toronto and Wisconsin, Catholic University of America, Rutgers, Vassar and Woodstock Colleges, New York State College of Agriculture and the College of Physicians and Surgeons

VOLUME
VIII

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THE MAKING OF A NEWSPAPER

How the World's News is Daily
Collected, Printed and Distributed

TELLING TODAY'S HAPPENINGS TODAY

WHEN you sit down to breakfast tomorrow morning with your favorite newspaper by the side of your cup of coffee, pause for just a moment and glance at the various headlines that meet your eye. Here on the first page may be dispatches from London, Paris, Constantinople and Peking; and as you turn the pages stories from other cities from far distant lands are there before you. And the dates themselves are almost all of yesterday. In the past twenty-four hours — since the last time you had breakfast — most of these events recorded before you have not only occurred, but have been chronicled by observers and sent by telegraph and telephone, by cable and by wireless; thousands of words over thousands of miles by all the means of modern science, to some great newspaper office where hundreds of men have labored day and night converting the dots and dashes of these messages into type, there to be met with vast rolls of paper made from the spruce of the forests of America or of northern Europe, and emerging in the small hours of the morning a printed paper — a daily miracle, a herculean task performed each twenty-four hours, to greet you at your table.

And if your imagination has been stirred sufficiently to hold you for another moment from the story that has, because of its concise, well-worded headline, even now subconsciously attracted your attention, let it wander over the variety of contents of the pages before you. Here is news of politics at state and national capital, of Congressional debate, of governmental appointees, of rulings of the courts; word from European capitals, of international agreements and disagreements, of massacre and disaster, of invention and discovery; news of science, of germs isolated and cures effected; market reports and records of financial transactions; births and deaths, marriages and divorces. Here are tragedy and comedy, drama and romance waiting for your eye, arousing your sympathy, your mirth, your sentiment. Here is a bird's-eye view of all the world, the recorded pulse of all mankind, the printed word which will influence your daily action and your daily life. How it is done, how the town crier has developed into the metropolitan daily of more than thirty pages, is a fascinating story.

Probably in few manufacturing plants is there such a degree of equality of importance between various departments as exists between the three B's of a newspaper office — the Brains, the Brawn and the Business — the news department, with the function of gathering and editing information; the mechanical force that prints and distributes the paper; and the business department that provides the wherewithal for all three to function. Each leans upon the other, each depends for its life on the other two, and yet each holds itself proudly aloof.

News, as viewed by a newspaper man, is a commodity, a raw material, in much the same sense as is the paper on which it is to be printed. And strange to say, it comes into the newspaper office in strikingly similar quantities, day in day out, with almost as much regularity as the rolls of white paper come off the paper machines and are shipped to the press rooms.

True, the news varies greatly in interest. Today's paper may be filled with matter that barely holds your attention and tomorrow's be so engrossing that the late evening finds you still reading it. Yet with the exception of the occurrence of some extraordinary event or the extra demands for space during some seasonal activity, such as baseball or the sessions of Congress, the quantity of news changes but little, and while your paper may vary in size, examination will show that this is largely accounted for by fluctuations in the amount of advertising carried. And as all things have some explanation, let it be said here that the reason is that news is for the most part not assembled in a haphazard manner, but is gathered, and gathered each day by the same forces and agencies exercising that news instinct or sixth sense which has been defined as knowing "where hell is going to break loose next".

The greatest of these agencies is the Associated Press, a mutual organization of American newspapers which has grown from 63 members in 1893 to about 1300 members in 1923. Each member can secure the same news as his fellow members and is also obligated to act for the association as a reporter in the event of any local news developing in his special neighborhood. The men who organized the Associated Press and helped to develop it to its omnipresence of today deserve as Melville E. Stone, its able manager for many years, writes in his "Fifty Years a Journalist":

"the lasting gratitude of the American people for having established, at a vast cost of time, labor, and money, a method of news gathering and distribution free from a chance of contamination. . . . Each of the 1300 members is either a partial or sole owner of a daily newspaper. These members have no common aim or partisanship of any sort. They are as varied in their advocacy of political, religious, or economic principles as it is possible for human beings to be. And this, they believe, is the best guarantee that the news they receive and print is and must be accurate, impartial and honest. Often they personally dislike certain of their fellow-members. They are at one on one thing alone; and that is that their news service shall never be tainted. There is no master hand of any governmental censorship, but there is a most exacting and jealous control of a highly sensitive body of intelligent editors with varying views upon every discussible subject, each one of whom has his voice and vote in the management of the institution. There is no pretence that the Associated Press is perfect, but it is believed to furnish the best-known method for giving to the American public an impartial service of news. The Associated Press . . . furnishes more than one-half of the news the American newspapers print, and its despatches appear in journals having an aggregate issue of over 20,000,000 copies a day. If the recognized formula of three readers for each copy be accepted, it is evident that its telegrams are read by more than one-half of the people of the nation. . . .

The world at large is divided, for the purpose of news gathering, among four great agencies. . . . Each of these agencies has a representative in the offices of the others. Thus the Associated Press bureau in London adjoins the Reuter offices (which gathers and distributes the news of Great Britain and the Far East). The telegrams to the Reuter Company are written on manifold sheets by the telegraph and cable companies, and copies are served simultaneously to the Associated Press bureau, the Wolff representatives (serving the Teutonic countries), the Havas men (representing the Latin nations), and the Reuter people. A like arrangement obtains in Paris, Berlin and New York, so that in each of these cities the whole panorama of the day's happenings passes under the eyes of representatives of each of the four agencies.

But the scheme is much more elaborate than this arrangement would indicate. Operating as tributary to the great agencies are a host of minor agencies — virtually one such smaller agency for each of the nations of importance. Thus in Italy the Stefani Agency, with headquarters in Rome, gathers and distributes the news of Italy. It is the official agency, and to it the authorities give exclusively all governmental information. It is controlled by Italians, but a large minority of its shares are owned by the Agence Havas of Paris, and it operates in close alliance with the latter organization. Thus, if a fire should break out in Milan, the *Secolo*, the leading newspaper of that city, would instantly telegraph a report of it to the Stefani Agency at Rome. Thence it would be telegraphed to all of the other Italian papers, and copies of the *Secolo's* message would also be handed to the representatives, in the Stefani headquarters, of the Reuter, Wolff, Havas and the Associated Press agencies. In like fashion, if a fire should happen in Chicago, the Associated Press would receive its report, transmit it to the American papers and furnish copies to the representatives of the foreign agencies stationed in the New York office of the Associated Press. . . . But the Associated Press is not content to depend wholly upon these official agencies. It maintains its own bureaus in all the important capitals, and reports the more prominent events by its own men, who are Americans and familiar with American newspaper methods. . . . Thus, with its alliances with the great foreign agencies covering every point of the habitable globe, . . . with

special commissioners to report events of great moment, with the correspondents and reporters of virtually all of the newspapers of the world laid under contribution, and with official recognition in a number of countries, the Associated Press is able to comb the earth for every happening of interest, and to present it to the newspaper reader with almost incredible speed."

Other agencies such as the United Press attempt as well to cover a broad field, and many smaller news services, dealing quite frequently in feature stories such as the memoirs or reminiscences of some prominent personage, contribute in broadcasting throughout the land the thoughts and deeds which later are called history. The great majority of small papers rely almost entirely upon services of this kind to augment the news of local origin which their own staff has gathered. A great metropolitan journal, however, maintains as well a staff of its own, with offices and special correspondents in the principal capitals and news centers of the world — London, Paris, Berlin, Rome, Moscow and The Hague — and in addition has arrangements in almost every city of importance which will insure the forwarding of dispatches in the event of any local disturbance or any requested information. The managing editor, sitting in his office in America, is able to marshal his forces and have them "cover" a situation that may arise anywhere in the world, thus enabling his paper to present each day to its readers a vivid and immediate picture of the event, assembling almost instantaneously facts which but a century ago would have been presented in our histories only after days or perhaps years of research and analysis.

THE COMPOSING ROOM OF *THE NEW YORK WORLD*
With its huge battery of linotypes ready to set the "copy".

It must not, however, be forgotten that with the exception of the reproduction of some document or the verbatim report of some speech the possibility of human error has to be reckoned with in all newspaper accounts. Actual facts themselves cannot be reproduced in all exactitude by either mind or pen and ink. Too often have you differed with some friend in whom you have implicit confidence as to what took place during some incident which you both witnessed, not to realize that an honest difference of opinion is not unusual. In an

endeavor to prevent this, and to fix responsibility a newspaper is careful to indicate the sources of its information, and the reader is either consciously or unconsciously affected thereby. If during the Great War those dispatches which emanated from Berlin had carried Paris date lines your fears would have undoubtedly been even more seriously aroused as to the ultimate success of the Allies. If your favorite daily published an Associated Press dispatch quoting General Von Ludendorff as saying that the Germans were successful at such and such a point you did not accept the victory as fact because you saw it in the paper or because the Associated Press transmitted it. Your mental reaction probably was that having faith in both of them you were certain that Ludendorff had been correctly quoted and you then proceeded to discount the statement made by him.

With a staff of specially trained correspondents in Federal and State capitals, with the home city perhaps covered by a local news association, as, for example, The New York City News Association, an organization built along the lines of the Associated Press, and a force of reporters, intelligent, wide-awake men watching every phase of political and social life, the office force of the news department of a great daily comes to work each evening knowing that already stories of the happenings of the world are being flashed over cables and through the air, that the widely spread service of gathering news is functioning and that before them lies their nightly task of assembling it into such form that it may be passed on to the mechanical department to be put into type and printed.

The news room, into which all this material flows, centers around the City Desk, to which all stories of local origin are brought, and the Telegraph Desk, which handles all news from out of town whether it be received by radio, from the tickers of the telegraph company located possibly in an adjoining room or from the automatic typewriters that carry the Associated Press service. Each of these desks has an editor in charge and about a dozen copy readers who carefully read each story as it passes through their hands, extract the substance from it and write the headline under which it will appear. Skilled work is this, requiring concentration and intelligence, for to write a story is one thing and to express its salient features truthfully in a few words is quite another.

Copies of these dispatches go to the managing editor and his assistants. With them rests the task of weighing the news, of finding its relative value for the purpose of placing it on this or that page in the paper, and fixing its positive value in determining how much space is to be allowed to it and what form of typographical display it merits. Here, also, a chance word may be the cause of cabling the London correspondent to secure a story of heretofore overlooked importance, and special arrangements being made with the cable company; a dispatch of many hundreds of words coming in sections over several wires arrives in time for publication that very night. In addition to all these stories of action there is a great task in securing and condensing the data which comprise the financial and business pages of a paper. Fractional quotation of stocks and bonds from the principal exchanges of the world must be set in type with painstaking care. Rates of foreign exchange, quotations of produce markets, bankruptcy notices and weather reports all must be classified, coordinated and made ready for printing. All through the night and frequently until after half past three or four in the morning the process of adding to and improving the contents of a large metropolitan paper goes on. As a rule, three editions are published — the first sent to distant subscribers, the second going out to the suburbs and the third being for general distribution in the city. Each of these is a later and consequently a better paper than the other and the constant efforts of the news department to hold each edition until the last moment so that it may be as complete as possible creates a problem which is continually taxing to the utmost the efficiency of the mechanical departments. Toward the middle of the evening the managing editor determines the size of the paper — that is the number of pages to be issued. He has

THE MACHINE THAT DOES THE COMPOSITION

The linotype is not a type-setting machine. No types are used in it. It composes with matrices — small brass units having characters indented in the edges, hence the name. These are assembled into justified lines. From the matrix line the machine automatically casts a solid slug, or line of type. It is ready for use when it leaves the machine. The matrices are automatically distributed, each in its proper place ready to use again. In the diagram on the left the cover has been removed to show the matrices leaving the magazine (at the top) when released by the pressure of the corresponding key by the operator, and traveling down the chutes to the "stick" or assembling mechanism. The slug, or line o' type, from which the machine gets its name, is cast in a "box" just to the left (not shown in the diagram, but visible in the larger picture).

A THREE-MAGAZINE LINOTYPE MACHINE

before him the number of columns of advertising that are scheduled to appear, and he estimates the amount of news, which, as has been pointed out, is comparatively constant. Once fixed, the word is passed along to the various parties interested and the mechanical department begins to take over from the news forces the major responsibility, until, as the night passes and the morning comes, the giant presses start pounding out thousands of papers per hour and the task of putting the newspaper beside your cup of coffee at breakfast is resting squarely on the shoulders of the "sons of Martha", as Kipling calls them.

There are four fundamental divisions in the mechanical department: compositors, stereotypers, pressmen and delivery forces. A story that has passed through the hands of a copy reader is conveyed automatically to a copy center in the composing room, whence it is taken by the operator of one of the battery of typesetting machines, who sets it in type and returns the copy and the type to a collecting center called the "bank". Typesetting machines have replaced almost entirely the old hand composition with "stick" and "rule". The machine is a marvel of ingenuity. The operator, by touching the proper lever on a keyboard similar to that of a typewriter, causes a matrix or mold of the particular corresponding letter to be released from a reservoir on top of the machine and to descend to a common center, where it is rapidly followed by the succeeding letters of the words in the copy before him. When a line of these matrices is full it is automatically pushed into a casting box, where molten metal is run on to it, thus casting a line of type. Once used, the matrices are lifted by the machine to the reservoir from which they came, and distribute themselves into their proper compartments, ready to fall again at a touch on the keyboard. Line after line follows until the copy has all been set and returned to the "bank". Here a proof is taken and sent to the proof room, where it is compared with the copy. The type is now ready for assembly in its proper place in the make-up of the paper as determined for it by the managing editor — or by custom, if, for example, it deals with some specific or routine matter such as market reports, which have a fixed place in the paper. The number of pages to be printed has been decided. For each one there is a "form" or frame in which the

THE INS AND OUTS OF COMPOSITION AND STEREOTYPING

THE conversion of the written into the printed word is a process of composing and stereotyping, consisting of alternate use of a mold and a cast made therefrom.

FIGURE 1 is the matrix (enlarged $2\frac{1}{2}$ times) used in the linotype composing machine shown on the preceding page. Note the mold of the character M on the left. After use in the machine this matrix is automatically returned to the magazine from which it originated by the help of the saw-like notches on the V at the top. These notches, somewhat similar to those on a Yale key, are different for each letter and so cut that the matrix can drop only into that compartment reserved for the particular letter.

FIGURE 2 is the assemblage of single matrices made up into words, spaced and "justified" to fit the width of the column.

FIGURE 3 is the line of type cast by pouring hot metal on the line of matrices shown in figure 2.

FIGURE 4 is made up of slugs similar to that shown in figure 3, assembled into a complete page and locked in a frame or "chase."

FIGURE 5 is a *papier-mâché* mold made by impression from the page shown in figure 4.

FIGURE 6 is the stereotype plate molded from the *papier-mâché* of figure 5 and ready to be clamped on to the press. The plate is made curved to fit the printing cylinder of a "perfecting" press, several such plates revolving face to face, the paper from an "endless" roll running between — like clothes in a wringer — and being printed on both sides simultaneously.

FIGURES 1, 2, and 5 are "ins" and read from left to right.

FIGURES 3, 4 and 6 are "outs" and read from right to left.

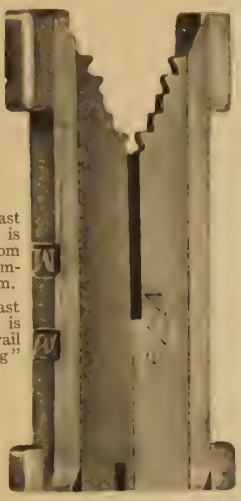


FIG. 1.

This character is cast when the matrix is riding on the bottom rail of the "assembling" mechanism.

This character is cast when the matrix is riding on the top rail of the "assembling" mechanism.

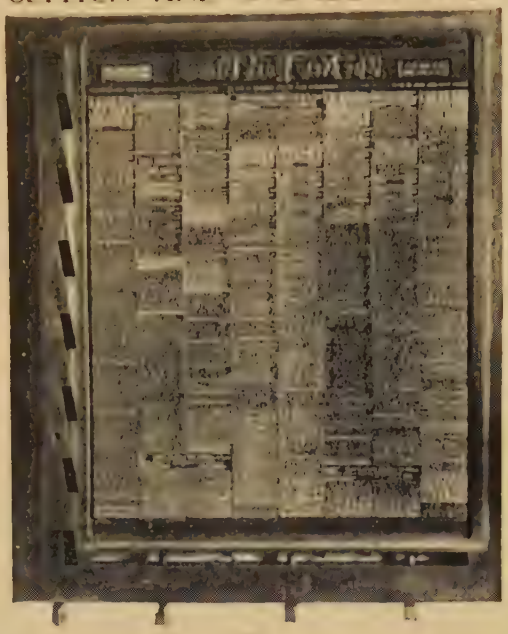


FIG. 4.

FIG. 2.

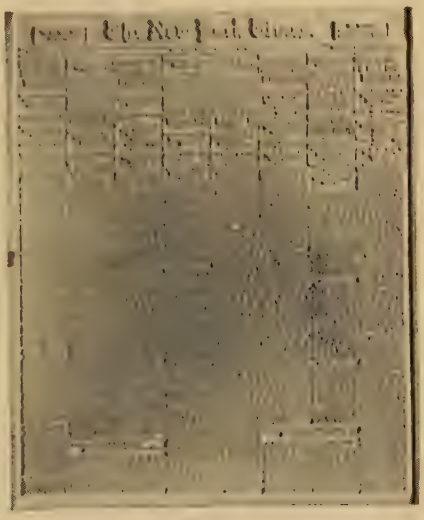


FIG. 5.

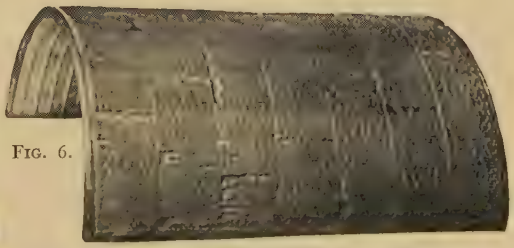


FIG. 6.

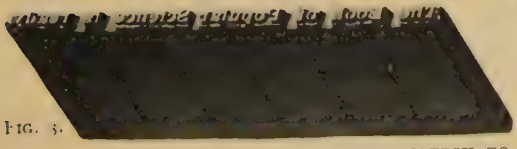
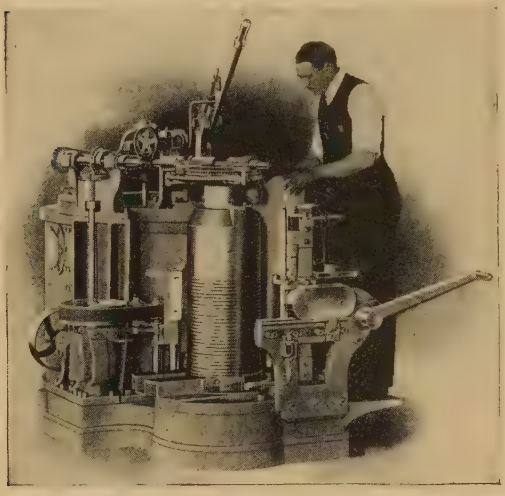


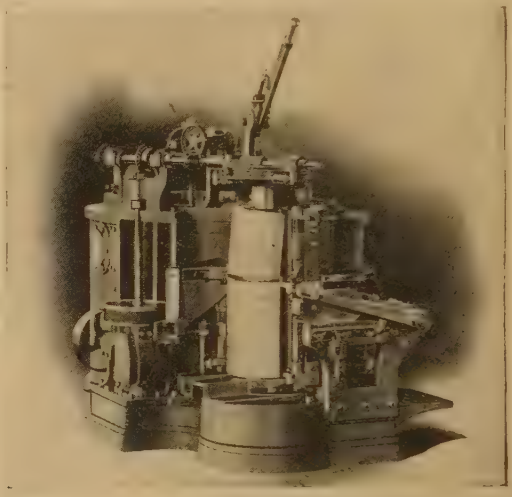
FIG. 3.

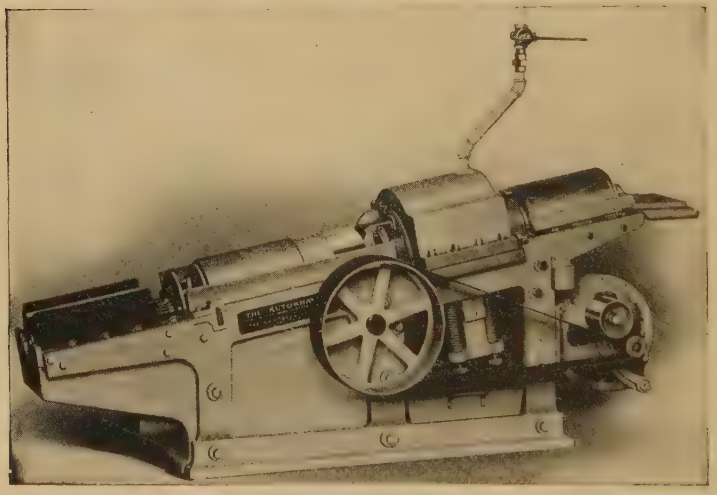
FROM MATRIX TO STEREOTYPE PLATE

(See page facing for explanation.)

advertisements have already been placed in accordance with the records of the business office and into which the type has to be clamped and locked so that the page of type is solid, even and on its feet. One cycle is finished — the paper has been started, and the burden passes from the compositors to the stereotyper. Each frame is wheeled to the stereotyping table where a sheet of thick paper resembling blotting paper is placed over it and by pressure and heat molded to the type of the page. Once more we have a matrix to cast from — this time of an entire page instead of an individual letter. The matrix or mat is then curved into a semicircle, the molded side in, in a machine called an "autoplate". Hot lead is poured onto it and as it cools and solidifies we have the curved plate, the reverse of the matrix, which a moment later will be clamped upon a cylinder of the press ready to lay the ink upon the clean white paper and make the printed sheets. Meanwhile the frames of type have found their way back to the make-up tables and are unlocked ready for corrections and alterations for later editions. The process of making mats and casting plates is done in the incredibly short time of less than ten minutes.







THE AUTOPLATE

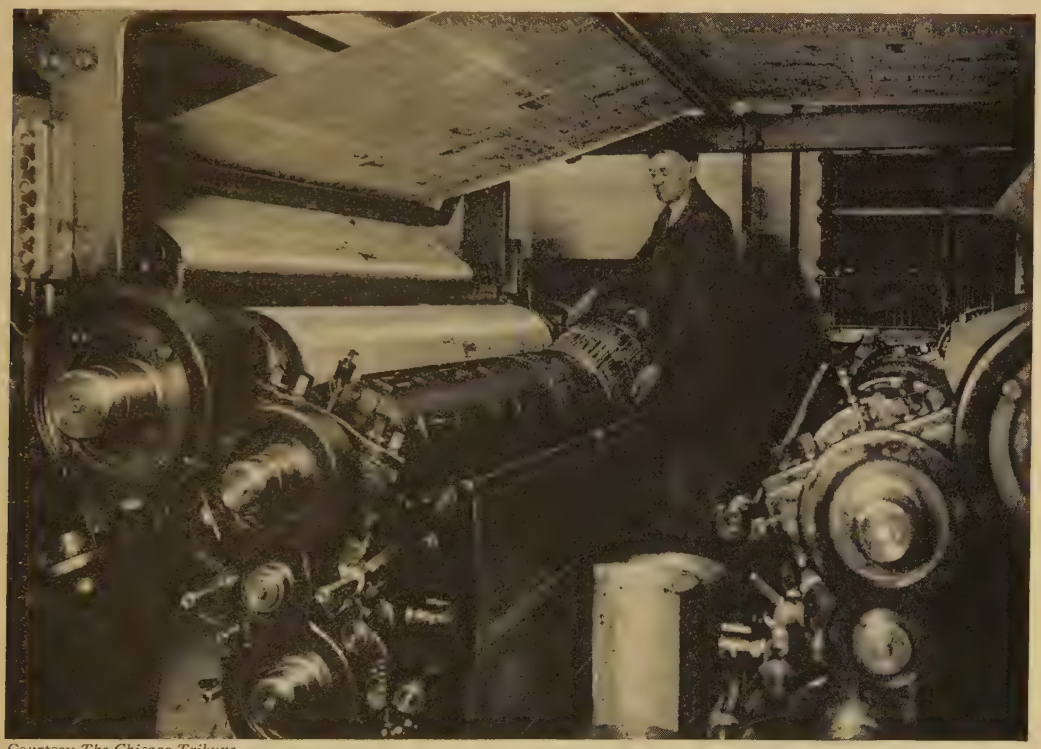
In the picture at the top on the left the *papier-mâché* matrix (figure 5 on page 2491) is being curved to fit into the casting box of the Autoplate. Hot metal is then poured on it and in the top picture at the right the finished plate (figure 6 on page 2491) is seen merging. Below is shown the plate finishing and cooling machine which trims the ends of the plate and bores the inside circumference of it to the exact size of that of the printing cylinder of the press. The plate is then sprayed, cooled and brushed and is ready for the press. There is a plate shown just entering this machine, one being treated, and one leaving the cutters to pass over the brushes at the end.

The press room of a paper like *The New York Times* is equipped to turn out more than a million and a quarter eight-page papers in one hour. During the year 1922 more than eleven hundred tons of white paper were consumed by it each week, about 60,000 tons per year, producing a quantity of printed sheets which if laid end on end would extend a distance equivalent to six times from Times Square to the moon.

For nineteen hours of each twenty-four these great rotary presses lie idle, sleek and clean, ready to run each night for the five hours from 12 : 30 to 5 : 30 A.M., and as the rolls of white paper are fed to them and are brought in contact with the inky plates, paper and news are combined to make newspapers which emerge from the press folded, cut and counted, to be seized by the waiting delivery forces and spread fanlike over city and country in train and motor truck, dividing and extending in all directions until, as the sun rises that affinity of the printed sheet for the coffee has been gratified and the newspaper lies complete upon your breakfast table.

Six days out of each week this process is repeated, and on the seventh a veritable library of current events finds its way to your home. Special articles bearing on the news of the week and elaborating it are presented to you. Pages are given to fashions and sports. Reviews of the various markets, the stage, the world of books, of politics and the arts, are set before you and, as in the case with some newspapers, pictures printed from etched copper cylinders hold your attention and graphically illustrate and amplify the news that you have read. This is the Sunday issue consisting frequently in the case of metropolitan dailies of 140 pages or more.

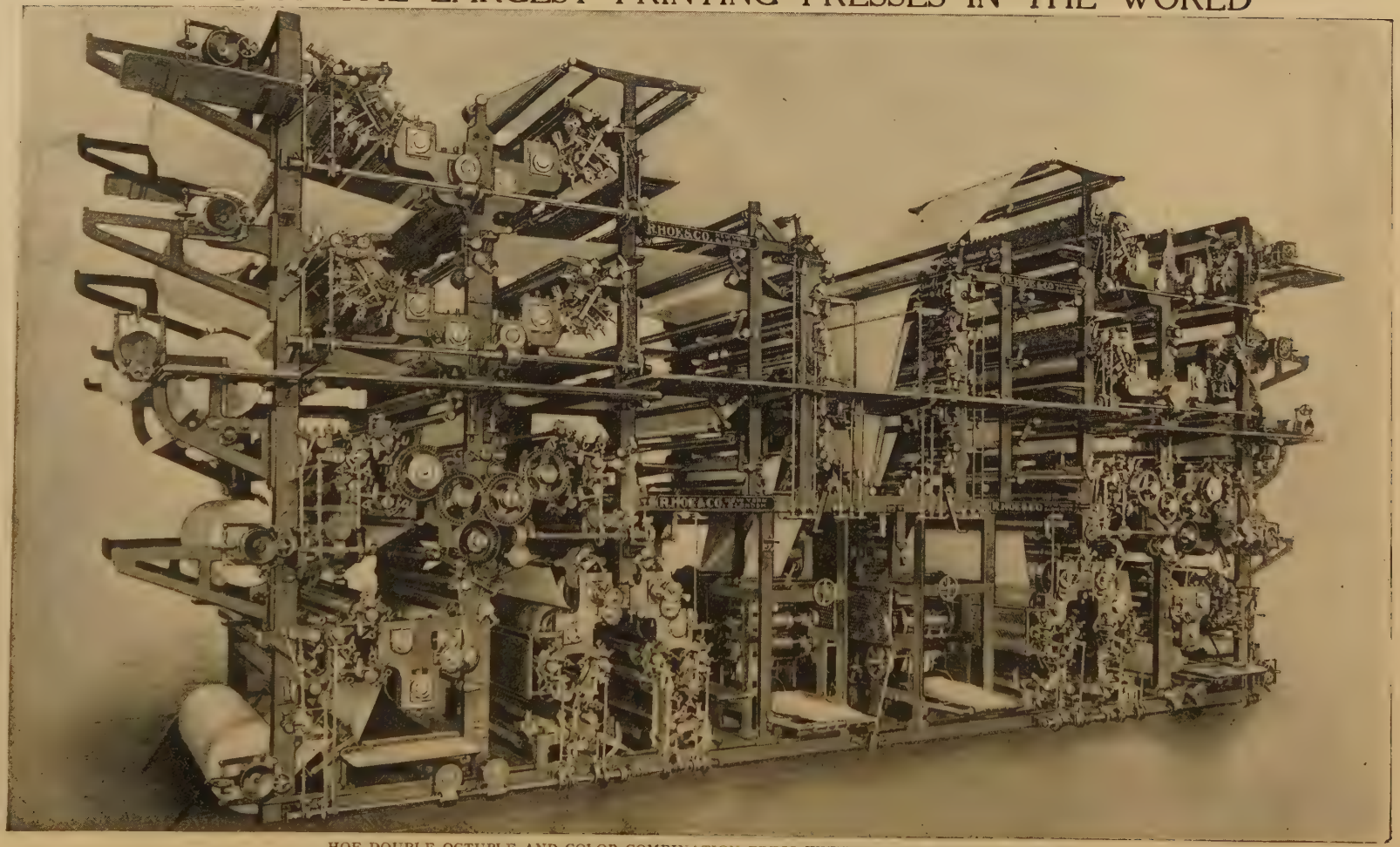
There are newspapers whose staff is composed of more than 1500 men and women who daily contribute directly in some manner towards its production. This does not include the many thousands who are associated with it indirectly, such as the Associated Press forces, the paper makers, or the employees of the news companies who assist in the newspaper's distribution. All this represents expense, however, and is paid for either directly by the newspaper in its payroll or is included in its bills for white paper or is one of the charges for the many associated services. In such an establishment the print paper cost alone runs into millions, yet, as a rule, the price of your newspaper in the city of issuance is only two cents for the daily and five cents for the



Courtesy *The Chicago Tribune*

CLAMPING THE CURVED PLATE ON THE PRINTING CYLINDER OF THE PRESS

ONE OF THE LARGEST PRINTING PRESSES IN THE WORLD



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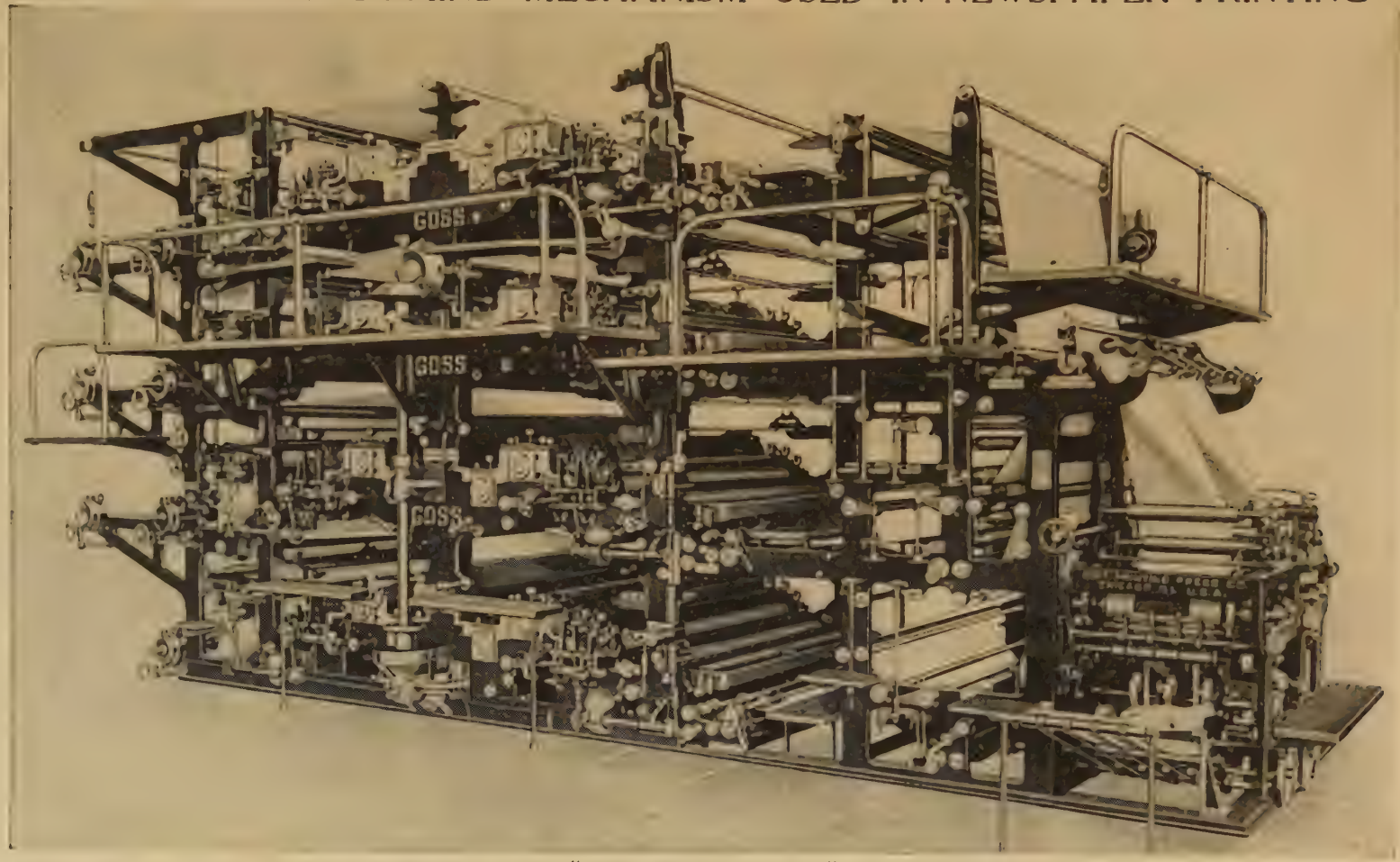

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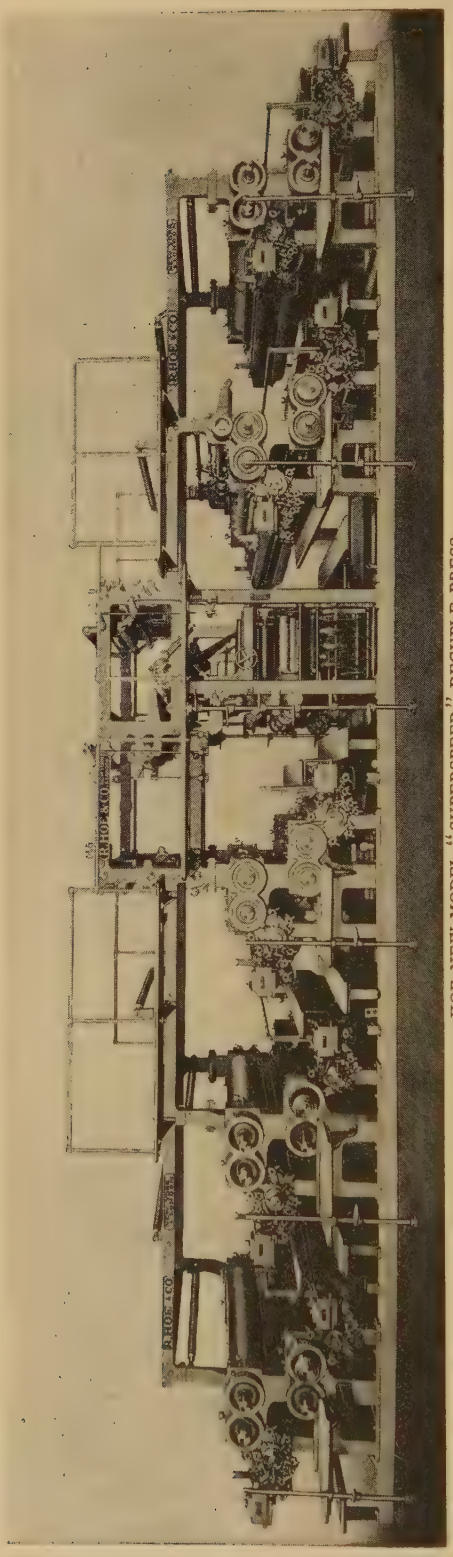

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Sunday copy. When you consider the fact that some forty per cent of what you pay does not reach the publisher at all, but goes to news agencies and dealers as part payment of the cost of distribution so that the net receipts from circulation do not even approximate the newsprint paper bill, it becomes obvious that a large revenue from advertisements is necessary to defray those items of personal service, raw material, machinery and overhead investment which make up the expense side of a newspaper balance sheet.

To secure this and to handle the large volume of business which produces it requires an able business staff, to whom honest advertising is as sacred a trust as is honest news to the news department, so that the rigid censorship to which many newspapers subject all advertisements in order to determine the accuracy of the facts presented is an important function of the business office. The theory that large advertisers control the policies of those metropolitan newspapers that they select as advertising media is rapidly losing ground and the mass of the reading public is already convinced of the fallacy of that assumption so far as reputable journals are concerned. The placing of advertising is now a simple business transaction — in which space, clearly recognized as advertising, is sold on a cash basis without any further complications or commitments than are associated with your buying the newspaper from your dealer. The same is true of all of a newspaper's many transactions, the disassociation of which from its editorial attitude is the realized ambition of every newspaper owner who is true to the best principles of his profession. To keep the news columns free from opinion is also the honest publisher's aim, and whether he be a Democrat, Republican or independent; radical, conservative or liberal, editorial views are found on the editorial page only — and the news of the day is published without reference thereto. So long as a newspaper follows this policy its position in the community is assured. It becomes a powerful factor for good government and is a lasting monument to good journalism.

THE BEGINNINGS OF MIND

Is the Soul in Every Cell of Life, and
Is Sensation the First Expression of Mind?

CONSCIOUSNESS THAT MAY BE EVERYWHERE

WE must be certain to begin our study of the mind at the beginning, or we shall sooner or later have to find our way back to it, and start all over again. The very elements of mind are to be found, of course, in the mind of man, but he displays mind in such a high and complicated form that we can scarcely recognize the units of which his mind is made. We must, indeed, go much lower in the scale of mind. The beginning for chemistry, until a few years ago, was the atom, and the way to reach the atom was by beginning with the study of an element like oxygen, not with the study of some hugely complicated compound like hæmoglobin. So here we find that the units of the mind can best be discovered by the study of the simplest minds, instead of the most complicated mind of all.

Such a mode of inquiry leads us instantly to the evident truth that the beginning, or unit, or simplest portion of mind is sensation. We rightly speak of "that which knows", but that which knows must first be that which *feels*. If you have no senses, no "gateways of knowledge", you cannot know. Therefore sensation comes first. It is the absolute beginning of all the phenomena of mind. We may probably go further, with much truth, and say that a single, simple, pure sensation bears much the same sort of relation to mind in general as an atom bears to matter in general. There, at least, is a clear and suggestive idea worth remembering, and easily remembered. It helps us, by an image which we can readily understand, to see the fact of sensation in something like its true relation to mind as a whole.

This is undoubtedly the right beginning for our study of the mind, but let us beware lest we get our right beginning wrong. We only have to think for a moment of the laws of chemistry, and the manner in which atoms behave according to fixed laws — such and such combinations making white of egg or water, and all these combinations depending upon physical conditions like temperature and pressure, electricity and so on — in order to say to ourselves: why should not just the same laws of physics and chemistry that apply to atoms, and therefore to all the phenomena of matter, apply also to sensations, and to all the phenomena of mind, which is built up out of sensations as matter is built up out of atoms?

This is far from being a new idea. On the contrary, any logical attempt to establish the doctrine called materialism, which declares that all the phenomena of mind are the consequences of the phenomena of matter, must prove, if it is to establish itself, that the facts of mind — as, for instance, sensations — have absolute, mathematical laws, just like the facts of matter. Hence the celebrated introduction of the new science called "psycho-physic", in the nineteenth century. The name implies, evidently, that there can be and must be a physics of the mind, and that we can reduce the working and behavior of the mind to mathematical formulæ like the working and behavior of stars, or chemical solutions or explosives. This new "science" will remind the reader of another "science", which is of still more recent origin, but has already fared badly at the hands of Time — the science of biometry, which tries to

measure life, and reduce it to mathematical laws. Obviously the psycho-physics of the German materialists, and the biometry of the distinguished English materialist Professor Karl Pearson, are different forms of one and the same thing. Here it is incumbent upon us to examine psycho-physics, and to decide what our relation to it is to be for the future.

It began with the work of two celebrated German physiologists, leading representatives of German materialism in the nineteenth century; and their names are commonly linked together in the celebrated "Weber-Fechner law", which is the basis of psycho-physics. This law is not too difficult to explain. Plainly, if mind begins in sensation, and if, as everyone knows, sensations differ in intensity, we must try to measure the intensity of sensations. Here is a field, and an absolutely legitimate field, for mathematics, which is essentially measurement. We throw a light into the eye, and feel the sensation of light. If the light be more intense, we feel a more intense sensation. So with hearing, or the sense of pressure, or any other. The light, the sound, the weight, whatever it be, is called a stimulus when it arouses a sensation. But the intensity of light or sound can be exactly measured in terms of physical laws; and nothing is easier than to experiment, first with a weight of one pound, and then with a weight of two pounds. Ought there not, now, to be a definite relation between the intensity of what strikes us and the intensity of what we feel? We all know that there is some relation, for the heavier weight feels heavier, the brighter light arouses acuter sight-sensations and so on.

The attempt to measure sensation as we can measure light

This fundamental question of the relation between the strength of the stimulus and the intensity of the sensation which it arouses was what Weber and Fechner set themselves to study. They obtained some extremely interesting and valuable results, showing how a certain minimum strength of stimulus is necessary before any of our sensations can be aroused, how the sensation increases in intensity when the stimulus increases, and how repeated stimulation — say, a series of little taps — will arouse sensation, though any one of those taps would not be felt or heard. Anyone can see that there is here an endless field for experiment, and we might devote chapters to results obtained in the study of any one of the senses along these lines. But what specially matters for us here is that these observations were declared to lead to a single, universal, exact, mathematical law, underlying all the operations of the mind.

This illustration will prepare us for it. If a light excites a sensation, twice as strong a light excites *not* twice as strong a sensation, but something rather less than that. How much less? When several and various observations had been made, some observers came to the conclusion that the rule is this: four times as strong a stimulus will produce only twice as strong a sensation; multiply the stimulus by nine, and you will intensify the sensation by three; multiply the sensation by sixteen, and you will intensify the sensation four times. Now, two is the square root of four, three the square root of nine, and four the square root of sixteen. So here is the possibility of framing a mathematical law; and this illustration will prepare us for the law laid down by Fechner, arguing from the observations of Weber.

An illustration of the simple and perfect conclusion of the so-called law

If the eye can recognize the addition of an eleventh candle to the light of ten, how many candles would have to be added to a hundred before one could recognize that the light was stronger? A moment's reflection will make us all agree that to spot the addition of one more candle to ten, and to a hundred, are very different things. Weber and Fechner came to the simple and perfect conclusion that, if you need add only one candle to ten, you must add ten to a hundred, a hundred to a thousand and so on. At any level of intensity of any sensation, a higher intensity of sensation can be felt when a certain fixed proportion of the original stimulus is added

to it — say, one-tenth must always be added for candles; so that if one could appreciate the difference between a thousand candles and eleven hundred, one could appreciate the difference between one candle and a candle and a tenth.

Hence, according to Fechner's calculations, we have what he called "the fundamental law of psycho-physics", and what we now call the "Weber-Fechner law", which states that "the intensity of a sensation increases in arithmetical progression as the strength of the stimulus increases in geometrical progression", or — in language which the mathematical reader will prefer —"the intensity of a sensation increases as the logarithm of the stimulus".

The absolute sterility of a law hailed with great expectation

This discovery aroused the greatest hopes in the minds of many. Here, it seemed, was something on which we could build a science of the mind, a psycho-physics, just as astronomy could build up a new science on the law of gravitation. But decades have passed, far more observations have been made, and all the boastings of the materialist have been dissipated. Psycho-physics is already dead, just as its younger brother, biometry, is moribund. The Weber-Fechner law, unlike the law of gravitation, has proved itself absolutely sterile. Nothing has come out of it. From Newton's law it was possible to predict and discover Neptune. No Neptunes of the mind, no least discovery, no illumination of any fact of the mind, has been derived, in all these years, from the Weber-Fechner law.

Why the so-called law for measuring mind can never be true

The explanation is very simple. The law is not true. What the law asserts is, very roughly, true for certain sensations, under certain conditions, in certain people, sometimes, within narrow limits. It is always quite untrue for sensations of very low or very high intensity. It is ridiculously falsified by practice, as when a musician or piano-tuner learns to know when a note is only very slightly out of tune. Every violinist, in the course of his education, has made a fool of the Weber-Fechner law. Now ask what bearing practice, experience, attention, a night's rest, a good meal, starvation, a dose of strychnine, a dose of caffeine, a dose of alcohol, have upon the working of the law of gravitation, and instantly we see that we have been talking nonsense. We have been comparing incomparable things. There can be no such thing as psycho-physics, for the sufficient reason that physics is physics and mind is mind.

Even Haeckel, many years ago, was compelled, much against his will, to acknowledge that "modern psycho-physics has fallen far short of the great hopes with which it was greeted twenty years ago". And if that had to be said of it, and by Haeckel, at the end of the nineteenth century, we need only add today that this supposed law has already gone to its own place with the rest of the puerile travesty of philosophy which men call nineteenth century materialism, and look back upon today with astonishment and "incredulous disdain".

The mistake of supposing that mind can ever be measured or weighed

Of course, exact methods must be employed as far as possible in the study of mind, and, of course, we must duly value such results as those which are so extravagantly valued in the Weber-Fechner law. Only we must never suppose our measurements of the physical, and therefore measurable, machinery to be measurements of mind, which, *by its nature*, cannot be weighed or measured. The Weber-Fechner law, in so far as it is true, and the similar laws of biometry, in so far as they are true, are one and all the laws of the matter which is associated with mind, or the matter which is associated with life — which is really the same thing. The Weber-Fechner law expresses certain occasional facts of the molecules that make up nerve fibers and nerve cells — in other words, it is a physical law; but as it happens to relate to physical things which are the instruments of the psychical, it has been thought to be a law of the psychical.

That is the confusion lying at the root of psycho-physics — a term which we now perceive to be pure nonsense, for it means the physics of the not-physical, an idea compared with which the threeness of two, the blackness of white, the squareness of a circle, the upness of down, are reasonable and obvious. Let us have done with this *ultimate* contradiction in terms — as if anything of sense or knowledge or wisdom could be erected thereon.

Points of touch between simple sensation and creative thought

We return, then, to what we have agreed to be the unit of mind, as it were, and that is a simple sensation. The problem now is to bridge the interval between the simplest form of sensation and conscious, creative thought. If our ideas are to be clear and useful, we must compare man with other forms of life about him, which will show us mind in simpler forms, though it is to be remembered that the greater includes the less, and that the simplest imaginable manifestations of mind may be observed in the reaction even of a Shakespeare at his desk, if he will but so much as run his pen into his finger.

In this comparative inquiry the psychology of our day has been immensely helped by the new biology, which is traveling ever further and faster from the mechanical lines to which it seemed to be bound at the end of the nineteenth century. The study of life has indeed come more than half way to meet the study of mind. A few years ago the comparative psychologist had a hard fight for it when he sought to gain acknowledgment for the existence of some sort of mind far down in the scale of living things. He was thought to be fanciful and paradoxical, and using his imagination unduly; but now, lo and behold, the biologists have continued their researches, and they have found signs of mind low down in the scale on their own account! And, finally, the philosophers of our time have begun to convince this generation that the splendidly sufficient reason why signs of mind are found everywhere in the regions of life is that life itself is really psychical.

Seeing the living, sensitive entities which were part of us a moment ago

It is now beyond dispute that sensation is to be found apart from the brain of the vertebrate; that it is to be found in the insects, in the amœba and in plants. It is also beyond dispute that, as we have said, the greater includes the less; and in man are to be found not only the manifestations of mind which are unique in him, but also those displayed in stages below him. Anyone may prove this for himself, if he has the apparatus, by pricking his finger and observing the behavior of the white cells in a drop of his own blood, seen on the warmed stage of a microscope. He will there see living, sensitive, independent entities, which were part of his own person a few minutes before; and when he remembers that a large proportion of the total substance of his body — say, about one-thirteenth — consists of his blood, which is crammed throughout with just such living, sensitive cells as he sees now under his eyes, he will be bound to realize that the greater does include the less, and even to ask himself what part of the sum of his *psychical* life may not, must not, be contributed by the psychical facts, the billions of sensibilities, of his white blood-cells *alone*, to name none other.

Explaining Haeckel's theory of the cell-soul and the immanence of mind

Here, beyond a doubt, the advance of knowledge entirely confirms the essential truth of the idea which Haeckel expresses by the term "the cell-soul" if by cell-soul is meant the sensibility or irritability of the cell. He is assuredly right in his assertion, though we may marvel at the conclusion which he draws from it, for to us nothing can seem clearer today than that to recognize the psychical in every living cell, and to admit that every cell has a psychical aspect — or "irritability" — is to lead us not toward the denial and dethronement of Mind, but to the recognition of it in some form as the essential part of all living processes. There, of course, is the crucial problem of interpretation; and we have to decide whether

the psychical aspect, now admitted to exist in every living cell of a man's body, is only an epi-phenomenon, as Huxley asserted the consciousness associated with the brain itself to be; or whether, indeed, the psychical bodily material of body-cells and brain-cells alike is not the phenomenon or appearance, while Mind is the reality which is there embodied, incarnate. The reader knows the answer which modern philosophy returns to this question.

Brain and mind both affected by lowered irritability of body cells

But now observe the consequences for human psychology of the discovery that the lower forms of life have an irritability, and therefore that all the countless cells of a man's body are indirectly contributory to his mind, not one whit less than to his body. If every cell had a soul, psychology would merely confound itself if it ignored the fact, and proceeded on the assumption that the brain is the *only* organ of the mind. Undoubtedly the brain is *the* organ — that is, the organ *par excellence* — of the mind, nor will its preëminence ever be challenged. It is universally accepted. But the brain and the mind are no doubt both affected by defective nutrition or lowered irritability of the body cells over which they rule.

The psychology of the astonishing colony of cells in a human being

In this sense the psychical aspect of all the living cells of the body can no longer be denied; it is asserted strenuously alike by Haeckel at one extreme, who believes that life and mind are reducible to matter and energy, and by Henri Bergson at the other, who believes that matter and energy are the creatures and instruments of life and mind.

Since, therefore, the psychical aspect of every living cell is now an undisputed fact — whatever disputes exist about its interpretation — clearly there is no room for dispute over the necessary inference that *human psychology must necessarily be affected by the state of nutrition and irritability of all of the cells that live together in the form called the human body.*

The futility of Herbert Spencer's theory that thought is everywhere

In Herbert Spencer's "Reflections" that writer attacks the assumption that the mind and the brain correspond, and Spencer has no difficulty in showing that that characteristic view of nineteenth century materialism is untrue. Thereafter, however, he says, "mind is as deep as the viscera". Now while we must grant that mind is affected by cells beyond the brain — for instance, the liver and stomach, which means the cells of which those viscera are composed — we cannot say that thought is everywhere. But we find Spencer, at the end of his chapter, writing a notable sentence when he says: "No less inscrutable is this complex consciousness which has slowly evolved out of infantine vacuity — consciousness which, in other shapes, is manifested by animate beings at large — consciousness which, during the development of every creature, makes its appearance out of what seems unconscious matter, suggesting the thought that consciousness in some rudimentary form is omnipresent". However, he seems to have confused himself into thinking that "consciousness" and "thought" are the same. A person who has lost his mind cannot think; but he is still conscious.

The intimate relationship between the body and the mind

The condition of the body, *therefore*, is far more important than its most materialistic champions had thought it, and we must study it with new insight, new care, new respect, new solemnity, because of the almost awful, palpable reality with which modern science applies to the body, and to all the body, the words against which science, falsely so-called, has long blasphemed — "Ye are the Temple of the Holy Ghost".

From a very different field of thought and inquiry we are now gaining confirmation of the view that, so to speak, the body, the whole body, is the physical complement of the mind — the view that the whole body, and not merely the portion of it called the brain, is, as it were, the visible, physical "double" of the invisible and

spiritual soul. The field we refer to is that of insanity and mental disease. The study of the abnormal mind during the last generation has not merely been valuable in the treatment of it, but has thrown strange new light upon the normal — upon the real nature of man. And the argument here presented is that the trend of knowledge in psychiatry, the science of mental disease, is precisely parallel to the progress made by normal psychology.

The trend today toward a greater study of the human mind

Here, also, beginning with the brain alone, men have been compelled to extend their inquiries until, by most unexpected and astonishing paths, they discover that the condition of the *whole* of the body, and not the brain only, has an ultimate effect upon the mind. If every cell has its own irritability and nutrition, what else can we expect than that the health and disease of the mind are the counterparts of the health and disease *not* of the brain only, but of every cell of the body as a whole upon which cells the brain depends for its sustenance?

That is precisely the conclusion of modern psychiatry. Unfortunately, in this country we are still behind in our study of this subject. The pioneer in the humane treatment of the insane was the immortal Frenchman Pinel; and it is today in France, Switzerland and Germany that are to be found the great leaders in this study of the mind in its aberrations, which throw such wonderful light upon the mind in its health. Here, until recently, we were in that state of darkness in which hypnotism was supposed to be inseparable from charlatanry, like that of the spiritualistic séance with its fake "manifestations". But when we turn to the great students and thinkers, we find their researches into the mental manifestations of what we roughly call insanity, in all its forms, leading them to the conclusion that the whole of the physical must be reckoned with if we are to understand the whole of the psychical.

The real truth is that long ago expressed in the ancient motto, "*Mens sana in corpore sano*" — the sound mind in the sound body; not the sound mind in the sound brain merely. For we discover that the entirely sound brain cannot exist except in an essentially sound body.

Mental phenomena not wholly dependent on brain which displays their symptoms

It is worth while to indicate the chief argument of the modern school, which insists upon the importance of the whole body in relation to the whole mind. For the full measure of the argument we should require to survey the great volumes on abnormal and morbid psychology, but the chief fact which they all express can be briefly and clearly stated. It is that we find morbid states of mind associated with brains that are apparently healthy in structure; and that, when thus driven beyond the brain and its structure for the key to the mental phenomena, we find that key elsewhere in the patient's body. The symptoms are displayed by the brain, and we blame the brain, but that is our unwisdom merely. The brain is an organ, and an organ requires conditions. Thus one may try to play a musician's organ in a vacuum, and no sound will issue. If we therefore blame the organ itself, so much the worse for us.

Just similarly the essential organ of mind, which we call the brain, is only part of a greater whole. It needs the brain and the rest of the body to display the music we call Mind, as it needs a pipe-organ and the atmosphere around it to embody the music of sound. This analogy of ours is not far-fetched. All of the characteristic and familiar mental phenomena of anæmia are due simply to the inadequate supply of nutrition to the organ of the mind, owing to the fact that the red cells of the blood are too few in number and too poor in hæmoglobin to keep the brain sufficiently well fed and oxygenated. It is impossible to work such a brain at the intensity which a better nutrition makes possible. Just so the organist cannot play a long fortissimo passage on a hand-pumped organ if the organ-blower is having a holiday, and only his ten-year-old boy is available for his task. The boy cannot

supply air enough; nor can the pale blood of an anæmic girl whose mental organ we are trying to drive at the intensity possible for a healthy, red-blooded person whose brain is richly supplied with oxygen.

That is merely one illustration, though perhaps a sufficiently striking one, of the truth that modern psychology must reckon not only with the essential organ of mind, which we call the brain, but also with all its accessories, which are indeed no less essential, though less obviously so.

Our body and its consciousness that develops from one cell

In future chapters this leading principle of psychology will become evident — as when we discuss the internal and organic sensations of the body, the facts of subconsciousness, dreams and the various forms of the "hypnotic state", so-called. The present necessary purpose will be served if the reader is fully prepared to accept the idea that the whole body, and the whole of the bodily functions, as we call them, must henceforth be reckoned with as having their psychical side and psychical significance.

The full measure of this theory of the body, and the attitude which modern psychology must assume toward it, is yet to be realized. It is involved in consideration of the fact that, if the body and brain of Shakespeare were developed from a single microscopic cell, which was the young Shakespeare, so also the consciousness of Shakespeare must have had its foundation in the same cell. This is the "consciousness which, during the development of every creature, makes its appearance out of what seems unconscious matter". Plainly the stress-word in that sentence is *seems;* plainly we have no choice but to acknowledge, in the first cell from which every one of us is developed, as much to come of *psyche* as of body. But what a truth to take the breath away this is!

The parallelism of mind and body at every stage of development

It needs no demonstration nor argument, once fairly stated; and it is evidently the logical antecedent of the principle upon which we have been trying to insist — that the whole of the developed body must be reckoned with in the study of the whole of the developed *psyche.* Plainly, mind and body are parallel at all stages. We can make no exceptions. Observe now what men were compelled to argue in the past, in that thick night which intervened between the day of antique learning and the dawn of science in our own day, beginning at the Renaissance.

All Christians believe that man has an "immortal soul" which dwells in the body during the life of the body but leaves the body after the body's death. The question now presents itself "When does this 'immortal soul' enter the body?" We must answer this question by saying that theologians differ as to the exact time; and science has no answer to give.

All powers and tastes and qualities born from the cell

Plainly, the psychical counterpart, double, aspect, or being of man, whatever we are to call it, has the same relation to the body and brain of an infant five minutes before its birth or five minutes after. The absolute necessity of logic drives us backward, from the adult to the child, the child to the infant, the infant to the fœtus, the fœtus to the embryo, back at length to the single cell, which arose from the fusing of the egg of the mother with the sperm of the father. But even this beginning had its beginners; and the self-control, the love of flowers or music, the bad temper of any one of us, may have passed to us from either of our parents. Such "inherited" qualities are thought to be conveyed by the chromatin or germ plasm in the sex cells at their time of fusion to form the original birth-cell or one-celled stage of the human embryo. Exactly what takes place and how it occurs is still a miracle.

Miracle and mystery enough to stagger sextillions of infidels

And, on the controversy regarding "miracles", we begin to realize what Pasteur meant when he said "*Tout est miracle*", or Walt Whitman when he said that "A

mouse is miracle enough to stagger sextillions of infidels". Indeed it is; for in all that we have been saying, except concerning an "immortal soul", the word "mouse" might be substituted for "man" throughout, and practically not a comma need be changed. Whether in mouse or man, or in any other such creature, the persistence of mental organization, in parallel with the physical organization, through the germ-cells from generation to generation, is indeed mystery enough "to stagger sextillions of infidels".

The consideration of man from his earliest stage, as a single cell, to maturity, has now taught us clearly that his consciousness must be "co-extensive" — if for a moment we may regard consciousness as having extension — with the *whole* of his body, whether and when that is a single cell or the adult body we know so well. This is clearly the only possible inference to draw from our modern knowledge of the development of the individual body.

The whole body conceived in psychical no less than physical terms

Here we have specially insisted upon this argument, because it is usually put in the background, while attention is specially directed to the parallel and analogous argument drawn from the whole history of the human species. In this, as in all other cases, we see the great principle of Von Baer — that the history of the individual is a sort of recapitulation of the history of the race. And so the argument that man's physical body and life are complementary to and parallel with his psychical being — and that the whole body must be conceived in psychical terms, no less than in physical — is equally valid, whether we trace the history of any man from his first condition as a single cell onward, or whether we trace the history of mankind at large from its early beginning.

Thus, to extend slightly an illustration employed by the writer many years ago, we may contemplate three objects in a row before us, (1) a man, (2) a white cell from that man's own blood, seen under the microscope, and (3) an ordinary amœba, seen under a second microscope. Now apply some disagreeable stimulus, such as a tiny drop of some irritant acid, to all three in turn. They withdraw; they exhibit consciousness of a definite kind. Toward other stimuli they will move, exhibiting consciousness of another kind. Chloroform, alcohol and so on will affect all three in similar ways, soon producing lack of response, abolishing irritability, anæsthetizing, if we may not say abolishing, consciousness in man, man's leucocyte, and amœba alike.

Body and mind co-equal, co-extensive, correlated, utterly one

Having thus examined extreme instances side by side under similar conditions, and having first prepared ourselves by recognizing that mind in its unitary simplicity is the power to feel, is *sensibility*, our simple observation teaches us once and for all that, whether we compare a man with one of his own tiny cells, or both with the humblest form of animal life we know (and any vegetable organism might have been added for completeness' sake), bodily life and mind are co-equal, co-extensive, correlated, of common origin, parallel, more utterly one, indeed, than words can say. The argument from evolution, the argument from embryology, the argument from psychiatry, the argument from comparative psychology, the argument from heredity — one and all lead us to the same conclusion.

And that is why we did well to use for our beginning the recognition of sensation, the power to feel, as the simplest mode of mind. Once that was granted, we found that mind was co-extensive with life — which is not only truth for the philosopher, but has a practical value for the student of man, meaning as it does that the study of man's psychology requires and employs the study of his physiology in every aspect. Nowhere is this fact better illustrated than in the physiology and psychology of the queen of the senses, which is vision; and to the study of the eye and of visual sensation we are now prepared to proceed. We shall find that the study of the eye is full of light for what shall follow for "the eye is the window of the soul".

PROBLEMS OF ALCOHOL

Its Importance as a Chemical Compound When Used Outside the Human Body

WHAT BECOMES OF IT WITHIN THE BODY

THE foregoing chapters have prepared us in some measure for the almost impossible task of discussing alcohol fairly and usefully. This cannot be done in a little space, nor can it be assisted by any dogmatic or personal assertions, as that alcohol is a poison, or that it makes one feel better. The problem affects our feelings and prejudices and antipathies and moral sense, but it is really a scientific problem, and in this place it must be treated as such. It is something that we have already reached some general principles as to foods, drugs and poisons, which will help us here, but our first concern must be to define the substance we are dealing with. It is, on all accounts, one of the most important chemical compounds in the world.

In the language of chemistry, there is a long series of substances known as alcohols, in correspondence with a similar and closely related series of ethers. For convenience, men usually mean a particular alcohol and a particular ether (the corresponding ether, in fact) when they use the terms without qualification. These are the second of the series, the first being known as methyl alcohol and methyl ether respectively. Methyl alcohol is of interest to us here, because its highly objectionable taste and smell practically preclude the use as a beverage of anything that contains it. In the United States the law forbids the sale of alcoholic beverages, but does not wish to prevent the use of alcohol for other purposes. However, people are always liable to drink alcoholic liquids, for whatever purpose they were intended, and thus defeat the purposes of the law. We therefore add to ordinary alcohol intended for use in spirit lamps, etc., a proportion of methyl alcohol, and the spirit is then said to be methylated. Methylated spirit is occasionally drunk by pitiable inebriates who can obtain nothing else, but, on the whole, the method of making the spirit undrinkable by adding methyl alcohol to it is effective.

However, a large and important problem remains for scientific ingenuity and legislative intelligence to solve, and it may briefly be named here. What we require for many commercial purposes, which daily increase, and may soon extend to the use of alcohol, like gasoline, in internal-combustion engines, is a spirit which shall be as nearly pure alcohol as possible, but which shall be undrinkable, either as such or when diluted or matured. A huge fortune awaits the inventor of such a spirit, but the problem is not simple. And we further require a government which shall do as it thinks fit in the taxing or prohibition of alcohol for drinking, but shall offer no obstacle whatever to the freest possible use of alcohol for all other purposes. For whatever conclusions we may reach as to the action of alcohol within a living organism, it is hard to beat for its uses outside the body.

It is a splendid fuel, clean and efficient and cheap; it is a wonderful cleanser; an almost unrivaled preservative, in consequence of its powerfully destructive action upon living matter, such as that upon microbes which cause fermentation or putrefaction; and it is a very nearly universal solvent, thus being of use for a host of chemical purposes.

A cheap and pure stream of alcohol is thus an essential for the industrial and material progress of any modern community; and it is most unfortunate that its liability to be drunk should interfere with the legitimate purposes for which there is an ever-increasing demand. For the problems of fuel and power are basal for a modern nation; and when we look at the natural history of this substance we find that when compared with such geological legacies as coal and petroleum, it occupies a very extraordinary position.

The "name in full" of the substance in question is ethyl alcohol, corresponding to ethyl ether, which is so familiar in surgery. The two substances are closely allied chemically, differing only by the lack of the elements of water in the ether, which is an oxide, while alcohol is the corresponding hydrate — *i.e.*, "watered" — and they are largely used together, with the addition of chloroform, in the very well-known "A.C.E. mixture" — alcohol, chloroform, ether — of the anæsthetists. Ethyl alcohol — as we shall call it for the last time — may be made by chemistry in a variety of ways, but in nature it has one definite origin. If we take a typical sugar and examine its chemical constitution, we find that it consists of carbon, hydrogen and oxygen atoms. Under certain conditions this large and complicated molecule, mysteriously made by the green plant, can be broken up into a number of smaller molecules of two kinds.

The natural formation of alcohol and its evaporation in baking

The two substances thus formed are carbonic acid gas and alcohol; and the process is illustrated in every loaf of bread we eat — except "aërated bread", into which the carbonic acid has been forced from without. When dough "rises", it is raised by the formation of carbonic acid gas within it, by the decomposition of sugar. Alcohol is formed at the same time, and evaporates. The alcohol consists, like sugar, of atoms of carbon, hydrogen and oxygen, but in very different proportions — viz.: two of carbon, six of hydrogen and one of oxygen in each molecule, or C_2H_6O.

The composition of alcohol is very important, even when stated so simply as this, for it shows at a glance that this must be a combustible thing, and also what the products of its *perfect* combustion — but note the adjective — must be. Plainly it must have a high fuel-value, with all that carbon and hydrogen to be satisfied in their demand for oxygen, of which they now have only one atom between them. Each carbon atom wants two oxygen atoms to make carbonic acid, CO_2, and every two hydrogen atoms will take one oxygen atom to make water, H_2O, so that plainly each molecule of alcohol is equal to taking up six atoms of oxygen, besides the one it has, for its complete combustion. We also observe that the products of combustion, carbonic acid and water, are the normal products of the combustion by which our bodies maintain their heat and energy, and that we have ample means of getting rid of them safely and quickly. These facts must be appreciated if we are to do justice to the argument, long maintained by physiologists, that alcohol must be a food in virtue of its chemical composition.

Alcohol formed from sugar and decomposed by typical fermentations

But we must first look further at the origin and fate of alcohol in nature. It was formed, we saw, from sugar, and now we learn that, in its turn, it is decomposed, and, by a very simple chemical change, is converted into acetic acid, the essential ingredient of vinegar, which is spontaneously produced from wine or other alcoholic liquors under certain conditions. Both of these processes — that by which alcohol is made and that by which it is destroyed — are typical fermentations. The first is effected by certain chemical ferments which have been successfully isolated from the microscopic body of the yeast-fungus, the *saccharomyces*, or sugar-mold. The second is effected by a still simpler type of fungus, the *bacillus aceticus*. This microbe is unique in nature, in virtue of its power of living by means of alcohol. The process is desirable when we want vinegar or acetic acid, but otherwise it is wasteful of a valuable substance.

Alcohol in sufficient concentration fatal to all forms of life

It is especially the formation, and not the decomposition, of alcohol that first concerns us, though we note how certain living cells, acting upon it, by no means necessarily yield such harmless or manageable products as carbonic acid and water. The fact may illuminate many other facts at a later stage. But the formation of alcohol is of immense interest. It can nowadays, thanks to the work of the great French chemist Marcellin Berthelot, be put together artificially from its elements in the laboratory. But under natural conditions we meet with it in only two situations. We find it, first and almost exclusively, produced in the vegetable world by the alcoholic fermentation of sugar, the agent being the yeast-fungus, so that alcohol has been called "the toxin of the yeast-fungus", like the toxins of other fungi, such as the diphtheria bacillus or the tubercle bacillus. No exception is known to the rule that, in sufficient concentration, alcohol is fatal to all forms of life — the fact which gives it its antiseptic value. The yeast-fungus which produces it may well be expected to be resistant to its action, and is so; but even in this case we find that when the fermenting fluid comes to contain a certain proportion of alcohol the fungi begin to die, the process is arrested, and if the fermentation is desired to proceed the alcohol must be continuously removed fast enough to permit it.

As to the importance of this familiar process. Wherever the green plant exists, there we find starch, which leads to sugar, and there we also find the yeast-fungus to form alcohol. Looked at as a source of power when subjected to combustion, this substance is therefore of extraordinary importance.

Extraordinary importance of alcohol as a universal source of power

Coal, oil, petroleum — these, as we have said, are geological legacies, and they cannot be used, like other capital, to yield interest and remain unimpaired. Further, their extraction involves serious economic problems, and tends to become a monopoly. Also, the crude combustion of coal is wasteful, and extremely injurious to the health of citizens. But alcohol, an alternative source of power, can be continuously produced, with extreme cheapness, wherever there is any soil upon which the sun shines. This source of power involves no expenditure and exhaustion of a nation's natural capital, but essentially depends upon the use of its natural income — namely, the sunlight which falls upon its surface. The time must necessarily arrive, and at no distant date, when considerations like these will penetrate even the stout walls of our legislative chambers. Meanwhile we shall have to decide how far the combustibility of alcohol, upon which its great economic uses depend, applies to the conditions and the relatively low temperature of the human body, or, if no combustion can occur there, what becomes of any alcohol that is taken into it.

But first we must go on to note the second, and most remarkable, situation in which alcohol has been discovered in nature. The fact is of high importance, because of its interpretation. Alcohol has been found to occur normally in the human body, no doubt in very minute quantities, but definitely and constantly none the less. It occurs in the muscles, and is found to be a product of muscular action. The chemical interpretation of this fact is in part clear. It is that a form of sugar is the normal fuel of muscular tissue, and that, apparently, when this sugar is oxidized for the production of muscular energy, alcohol is one of the products, or a stage in the series, or one series, of the products.

Alcohol made in the human body and destroyed in the body

It is impossible to be more definite at present. But at least we can be sure that the alcohol does not remain as such; for if that were the case, either it would shortly accumulate and kill the muscle, or else it would require to be excreted by the kidneys or lungs, or both. But we find no

alcohol whatever in any of the excreta of an animal or a human being to whom alcohol has not been administered. It follows, therefore, that the alcohol made in the muscles must be destroyed in the body; and, as we never find alcohol in the blood unless the drug has been administered, we must conclude that the alcohol formed from the sugar of the muscles — doubtless by some ferment they contain, comparable to that of the yeast-fungus — must be decomposed in the muscle.

The presence of alcohol in the body no warrant for putting more there

It goes without saying that this more or less recent discovery of the production of alcohol in the normal body under certain normal conditions has been seized upon as an argument in favor of its utility and the natural propriety of consuming it. In point of fact, the formation of alcohol in the body proves nothing, for the body is known to produce the harmless, necessary substance water; and, on the other hand, an interminable list of poisons, such as carbonic acid and uric acid. The question whether alcohol is to be classed with water, on the one hand, or any of these others on the other hand, remains where it was. Nothing is altered, except our belief in the honesty of those who advance such arguments.

They must not blind us, by their dubious advocacy, to the fact that the combustion of alcohol in the muscles, even if it be only partial, must involve the production of energy in proportion to the degree in which it occurs. But even supposing this oxidation to be such as serves the muscle, we are not entitled to argue that the administration of alcohol by the mouth would serve the body as the formation and destruction of alcohol inside a muscle is supposed to serve on this assumption. For, in the artificial case, the alcohol must be conveyed to the muscle by the blood, in which no trace of alcohol ever occurs normally, and in which it is therefore an essentially foreign substance, and upon which experiment has proved it to exercise a definitely poisonous and destructive action.

The rapidity with which the body gets rid of alcohol

This is perhaps the most convincing of the various answers to those who have argued for the administration of alcohol by the mouth because it is formed in muscles — an argument which urges us to breathe carbonic acid, which is also produced in muscles.

But this new discovery of the production and combustion of alcohol, in however minute quantities, in the normal working of the body, naturally leads us on to the first question which the physiologist must inevitably ask of this or any other thing that is introduced into the body: What becomes of it?

Unless we can answer this direct question of any food or alleged food, of any drug or poison, we cannot make much progress. We know that the law of the "conservation of matter" — apart from radioactive decomposition of atoms — obtains in the body as out of it. If we introduce any element or compound into the body it either stays there, or leaves the body unchanged, or leaves the body in some altered form, or does any two of these things, or all three. If it remains in the body, then its action will be cumulative, as is the case with mercury, and the fact may have mortal consequences. That is very far from being the case with alcohol. It does not accumulate in the body, because the body deals with it, in two distinct ways, as we shall see. No doubt a proportion of alcohol is always present in the blood of those who regularly take more than a certain small or moderate quantity, which varies with the individual and with many other factors, but that does not mean that the drug is cumulative. Let the heaviest drinker stop drinking, no matter after how many years, and in a period of time only to be measured by hours, probably — perhaps thirty-six or so — no alcohol will be found in his blood.

The body therefore deals with this substance, and it does so as quickly, thoroughly, and variously as it can; no poison is known which the body makes heartier efforts to dispose of.

The body's power of oxidizing alcohol beyond recognition

We have seen that alcohol is combustible; and the first question is to determine whether it is oxidized or burnt in the body. We might expect this to be impossible, for certainly alcohol cannot be burnt outside the body at any such temperature as 99° F., which is approximately that of the blood in the deeper and warmer parts of the body. But the body has special means of its own, and can, for instance, burn sugar at that temperature, which we cannot do outside it. The question must be therefore subjected to experiment, and then we find that under certain conditions *all* the alcohol given must be oxidized in the body, for none of it can be found in any of the excretions; and under any conditions and in any dosage we never succeed in recovering from the excretions all the alcohol given. Alcohol is therefore oxidized beyond recognition in the body; it is, in fact, turned into some other thing or things.

The body's protection found in changing alcohol to something less harmful

Here, again, its champions formerly permitted themselves the expensive luxury of a bad argument, assuming that, because alcohol is destroyed in the body, it is therefore oxidized into carbonic acid and water — the first, readily removed, the second harmless in any case — and that, in being so oxidized, it yields the corresponding measure of energy for the purposes of the body. But no proof of this has ever been attempted; and our entire lack of any title to assume that this is what happens is furnished by the best known and most natural case of the destruction of alcohol by fermentation at low temperatures, in which, as we have seen, the product is not carbonic acid and water, but a new and by no means inert or negligible substance — acetic acid.

A second comment upon this oxidation of alcohol within the body is that it is only a fact parallel to the oxidation of many other poisons, such as morphine. When that drug is administered the body proceeds to destroy it as fast as possible by oxidation. No one, however, proceeds to argue that morphine is therefore a food and a valuable and legitimate source of energy; but then it is to no one's interest to advance a palpably bad argument in this case. The probability is very high that the case of alcohol is similar to that of numerous other oxidizable poisons: the body seeks to protect itself by oxidizing them, and thus converting them, if possible, into something harmless, or less harmful — which is probably the more accurate statement both for morphine and alcohol. But there is a notable and important difference — namely, that the body can deal with vastly larger quantities of alcohol than of morphine.

The problem of what happens to alcohol that ceases to be alcohol in the body

Careful experiment has shown that if it be taken in small doses at a time, well diluted, at sufficiently wide intervals throughout the whole period, about one and a half ounces of alcohol can be administered in twenty-four hours, without any of the drug being recoverable from the excreta during that period or after it. Roughly speaking, this quantity corresponds to about three ounces of whisky in that period, but they would require to be taken as no form of alcoholic beverage ever is taken except for experimental purposes, if none of the drug were to be recovered. Calculations can be, and have been, readily made showing that the perfect combustion of this quantity of alcohol daily must involve the production of a very substantial and valuable quantity of energy for the purposes of the body. The only thing lacking here is any evidence that the combustion is perfect, or remotely approaches perfection. That has been assumed, and the name of science has been taken in vain, by authors who were, of course, perfectly familiar with the formation of acetic acid from alcohol.

In point of fact, no one yet knows what happens to the alcohol which ceases to be alcohol in the body. That it ceases to be alcohol is the sole fact which science has discovered so far, and therefore the sole fact which it is entitled to state, but the

question cannot and will not rest there, for we now want to know not only what happens to alcohol administered to the body and not excreted as such, but also to the alcohol which is normally made in the body and not excreted as such. Meanwhile we proceed to study the second mode in which the body deals with alcohol administered to it beyond a certain small quantity under certain strictly limited conditions.

The variability in the action of volatile drugs

As we have seen, the body excretes it as it is; and observation has revealed several very remarkable facts about this process — acts which chiefly depend upon the high volatility of alcohol, and the extreme quickness with which it can pass through most or all organic membranes, such as it encounters in the walls of the blood-vessels and elsewhere.

This easy and rapid passage of alcohol in almost all directions has results which are similar to those found in the case of other drugs with the same property, as, for instance, iodide of potassium, a very valuable and widely used and potent medicament. The iodide is found to be leaving the blood by the kidneys a few minutes after it is swallowed; but, on the other hand, small quantities may remain in the body for not merely hours, but days, after a single dose, because the drug is so easily absorbed by the blood from the stomach, is excreted in the saliva into the mouth, is swallowed again, and so goes on a curious circle which may last a very long time indeed.

Alcohol highly volatile and yet capable of being long retained

Similarly, it has been shown that a single dose of alcohol may exhibit its action for from thirty to thirty-six hours, so that most "moderate drinkers" are continually under its action for the whole of adult life. Yet the greater part of such a dose is removed from the body with great speed. The remainder may be accounted for in two ways. Some of it goes on a curious course rather like iodide of potassium. Absorbed from the bowel or stomach, it is carried to the liver, which largely exists in order to reject unsuitable constituents of the blood which reach it from these great surfaces of absorption, and the liver stops it and returns it to the bowel in the bile. But there it is reabsorbed and goes to the liver again. This circular and self-defeating process is probably accountable for the peculiar liability of the liver to be injured by alcoholism. The hobnailed liver of the drunkard, the failure of which ultimately kills him, is one which has itself gone to its death in the effort to protect the noble organs — above all, the brain — from this substance; and apparently the misfortune for the liver is that, by the mechanism we have mentioned, it may be compelled to deal with a given portion of alcohol not once but many times.

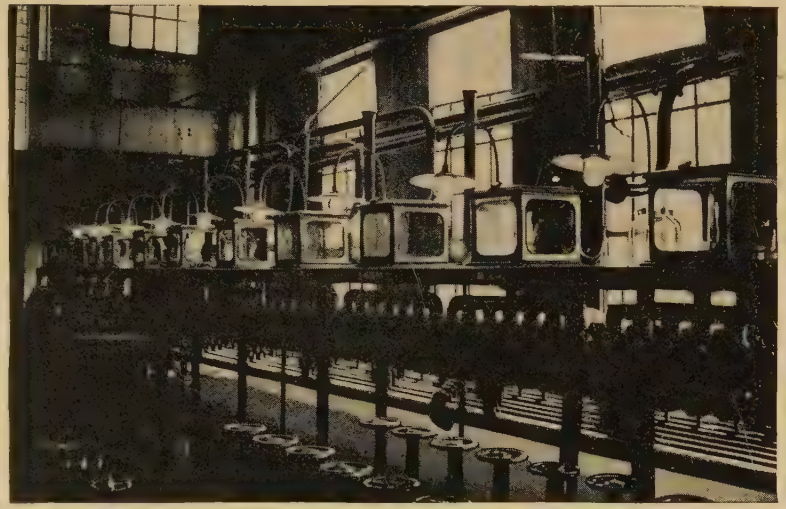
The peculiar affinity of alcohol for nervous tissue

The second way in which a dose of alcohol may be accounted for, apart from its actual excretion, and in which we have the key to the prolonged action of so mobile a drug, is its peculiar affinity for nervous tissue. The subject is difficult and still obscure. Twenty-five years ago it was known that this peculiar affinity exists, for alcohol could even then be chemically detected post-mortem in the brain, and in the fluid which is contained inside the brain, when no trace of it could be found elsewhere.

This fact goes with the observed properties of alcohol, which is, above and after all, a narcotic — one of the class of nervous poisons. Always its action is preëminently upon nervous tissue, from the highest levels of the brain downwards. We now know that a real chemical affinity exists between alcohol and nerve-cells, and that thus a certain portion of this extremely mobile, volatile, diffusible substance, which enters and begins to leave the blood and the body a few minutes after swallowing, is nevertheless detained or trapped *en route*, whenever it happens to run in blood-vessels that supply the nervous system, and may there produce results for many hours.

WHAT PRIVATE ENTERPRISE IS DOING TO SOLVE THE PROBLEM

BALTIMORE WORKS OF THE UNITED STATES INDUSTRIAL ALCOHOL COMPANY



DISTILLING BUILDING: TAIL BOXES

DENATURING PLANT

The study of alcohol in comparison with similar and contrary drugs

More recently the comparative method has thrown light on these observations. It is of little use to study any one drug or food by itself. Similar and contrary drugs should be compared and contrasted. Alcohol, chloroform, ether, allied chemically, notably similar in physical properties, and no less similar in their action upon the nervous system as typical narcotics and anæsthetics, and all three often the object of similar cravings on the part of unfortunate persons, require to be studied in parallel if their similarity of action is to be explained. Such comparative study seems to show that these three substances, and certain others chemically allied to them, but less familiar, have the property of being able to dissolve the peculiar fatty materials, called "lipoids", which are believed to furnish a sort of protective envelope for nerve-cells; and it is this solvent action upon the lipoids which gives these drugs their access to the much guarded privacy of the nerve-cells, and thus leads to arrest of their action. Such, at any rate, seems the probable explanation of this part of the action of these and other anæsthetics.

We had to mention that matter here, because we had to understand why such prolonged results follow the administration of a drug which, we asserted, is excreted with extreme rapidity. That excretion must be further studied. The rapidity of the processes is astonishing. The absorption into the blood of alcohol administered when the upper part of the alimentary canal is empty begins at once. It is estimated that one minute would suffice for a blood corpuscle to make the round of the circulation. No wonder that the action of alcohol is quickly exerted.

The organs that protect the body from alcohol the first to suffer

But it leaves the blood with no less speed. When it was applied to an absorbent surface it passed into the blood "like lightning"; when the blood carries it to an excreting surface it seems to leave the blood as quickly. This does not mean that the white cells, for instance, may not retain portions of it, for they doubtless do, just as nerve-cells do, but the point is that the body starts instantly with the business of excretion. Every surface and tissue whose business is of this kind takes a hand. We have seen the behavior of the liver, and now we have to observe the behavior of the organs reached by that proportion of the alcohol absorbed which the liver failed to arrest; for the blood-stream is quick, and though the liver stops much, it can never stop more than a proportion, as yet undefined.

The chief organs of excretion are now the kidneys and the lungs, the latter being available for any substance, such as alcohol, which is volatile. Accordingly, the drug is found in the secretion of the kidneys and in the expired air in a very few minutes — as few as twenty — and a diminishing proportion of it continues to be found there for hours afterwards. We may note that the kidneys closely follow the liver in their liability to damage by alcohol, probably because the drug must have more action upon those cells which select it from the blood than upon those which allow it to pass by them more readily. And we note, further, the potent action of alcohol in weakening the resistance of the lungs to consumption, as we shall see later. The general conclusion seems to be that the local-destructive action of alcohol falls most severely upon those organs which do their best to dispose of it for the protection of the body as a whole, and which are thus liable to special damage.

The importance of the study of alcohol as a separate ingredient

Our primary question as to what happens to alcohol when taken into the body has now been answered with some definiteness, though much more is needed, and we are in a position to proceed. Of course, the reader clearly understands that when we say alcohol we mean the definite substance, of definite chemical constitution, which chemists call ethyl alcohol. The attempt to deal, at a gulp, with all the

variety of substances contained in alcoholic beverages may succeed, in swallowing, but not in science. No one drinks pure alcohol and water. Many alcoholic beverages contain a variety of substances which are totally dissimilar in origin and properties — beer, for instance. Here our concern is with the alcohol contained in these beverages, or in any pharmaceutical preparation, such as tinctures and essences, or elsewhere.

The bulk of the beverage containing the alcohol of small account

It is essential, also, if our inquiry is to be useful, to realize that the quantity of this substance taken is the essential thing, and not the bulk of fluid in which it is taken. Whisky and beer are both alcoholic fluids, in that they both contain alcohol, but unless we know that the one is nearly half alcohol and that the other is only about one-fiftieth alcohol, we can make no useful study of either. What matters in alcoholic beverages is not their water, nor their flavoring matter, nor their coloring matter, but their alcohol.

It is this definite entity, found in various proportions in various fluids, that we are here discussing, and we have now stated its chemistry and have traced the various fates of a dose of it administered to the body. We have seen that in part it is oxidized, though whether that part is wholly or at all oxidized *completely* no one yet knows, the probabilities being against that supposition; and that in part it is excreted, primarily by the chief organs of excretion, and secondarily by any others that may be available, such as the breasts of a nursing mother.

The various forms of alcohol and the problems they raise

We must now proceed to discuss its action within and upon the body in health and disease. But this chapter may conclude with brief reference to a third member of the series of alcohols, of which the first was called methyl alcohol, and the second ethyl alcohol. A somewhat later member of the series is known as amyl alcohol, or, in its crude state, as fusel oil.

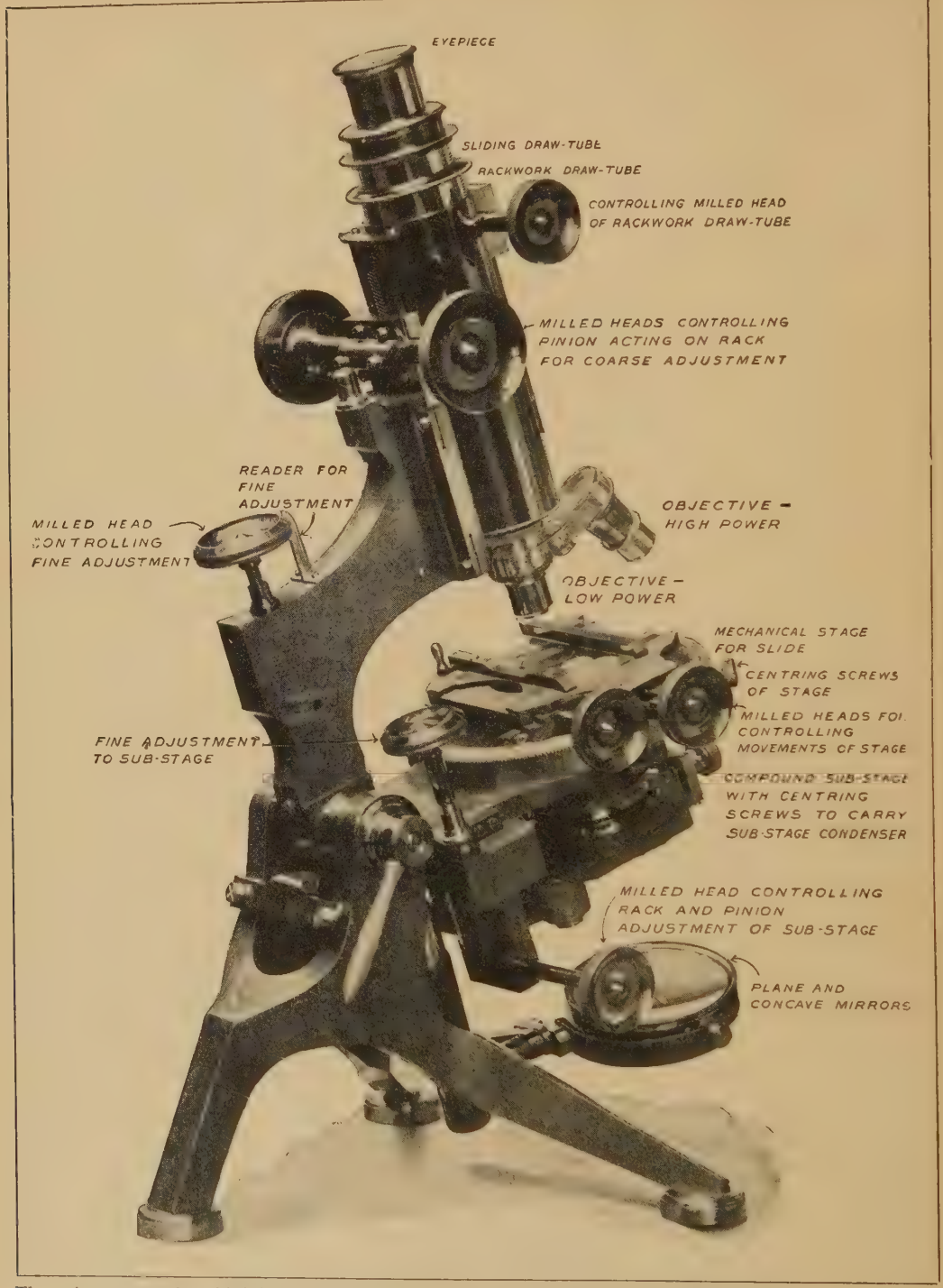
It has a very definite physiological importance, especially in parts of the world where raw, crude spirits are at all largely consumed. The process of formation of spirits from grapes, cereals or potatoes is very complicated, the fermenting material being extremely complex to start with. Many alcohols and ethers and other bodies are formed. Many of these are highly offensive; and the process of maturing whisky and brandy, etc., depends upon the gradual removal or destruction of such substances. Amyl alcohol is far the most important, having a directly deliriant action upon the brain.

Ill effects of alcohol due to the drug, not to anything combined with it

We insist upon the important characteristics of this particular impurity because its presence naturally opens the way to an interesting argument in defense of alcoholic liquors when their ill effects are commented upon. The argument is that those ill effects are due to the pernicious impurities contained in low-grade and cheap alcoholic liquors, to which those sold by the apologist in question doubtless form so conspicuous an exception. Hence the cry arises for good and pure liquors, and alcohol itself is relieved from the odium cast upon it. We have seen how the special properties of amyl alcohol support this contention. For the rest, there is nothing in it. The results described as following the administration of alcoholic liquors in general have been proved to be due to the alcohol; and anyone may destroy himself or others as easily with one as with another, according to the actual quantity of alcohol that it contains.

It finally should be said that alcoholic liquors contain no medicinal substance of any importance, other than alcohol itself, just as they contain no other deleterious substance of any importance, apart from the amyl alcohol in crude spirits.

Having thus arrived at the often-contested but now well-established conclusion that, for good or for evil, what matters in alcoholic liquors is their alcohol, we may proceed to trace its action in detail.


EYEPIECE
SLIDING DRAW-TUBE
RACKWORK DRAW-TUBE
CONTROLLING MILLED HEAD OF RACKWORK DRAW-TUBE
MILLED HEADS CONTROLLING PINION ACTING ON RACK FOR COARSE ADJUSTMENT
READER FOR FINE ADJUSTMENT
MILLED HEAD CONTROLLING FINE ADJUSTMENT
OBJECTIVE — HIGH POWER
OBJECTIVE — LOW POWER
MECHANICAL STAGE FOR SLIDE
CENTRING SCREWS OF STAGE
MILLED HEADS FOR CONTROLLING MOVEMENTS OF STAGE
FINE ADJUSTMENT TO SUB-STAGE
COMPOUND SUB-STAGE WITH CENTRING SCREWS TO CARRY SUB-STAGE CONDENSER
MILLED HEAD CONTROLLING RACK AND PINION ADJUSTMENT OF SUB-STAGE
PLANE AND CONCAVE MIRRORS

The microscope, the chief instrument of modern science, by showing the unimportance of size, has brought back the dignity robbed from man by the telescope.

SEEING THE HITHERTO INVISIBLE

How the Microscope Magnifies Man's Range of Vision
and Reveals a New World of Life and Movement

THE CHIEF INSTRUMENT OF MODERN SCIENCE

WE are all familiar with the simple magnifying glasses by means of which we may look at a part of a flower or a blade of grass and find the appearance greatly changed. The flesh on one's hand, when seen through such a glass, appears rough and coarse no matter how smooth and fine it may look to the naked eye. Yet these little instruments magnify but a few diameters. That is, an object seen under one of them seems to be only a few times larger than it appears to the unaided eye. Let us imagine, then, if we can, how great a change there is in the appearance of the same object when looked at through an instrument which magnifies many hundred times.

The microscope consists of a series of magnifying glasses mounted together in a suitable holder, the shape and adjustment of the different glasses being so related that they all work together to produce in the eye that looks through them an enlarged image of the object which is being examined.

It would be impossible to enumerate the services which this instrument has rendered and is rendering to mankind. Most of our knowledge of disease germs is directly dependent upon it. So also is our knowledge of the structure of the human body. The biologist would be helpless without his microscope to aid him in his study of the processes of growth in plant and animal. The laboratory of the chemist would be as incomplete without the microscope as it would be without the flasks and beakers.

All of these things are of great importance in our daily life. The knowledge of the physician and the biologist enable us to feed and care for the body properly; the work of the chemist enters into practically every process of manufacture. He determines what components shall enter into our food, the paint for our houses, the iron and steel and brass of which our buildings and machinery are built. In all of these his work is made possible by the microscope. The manufacturers and users of iron and steel are today relying very largely upon photographs of cut or broken sections of the metal to tell them its quality and reveal its defects.

By means of the microscope, objects about a quarter of a millionth of an inch in size can be distinguished from each other and photographed. By the ultra-microscope still more minute things are made visible — one-sixth of one-millionth of an inch is the present limit — and when the ultra-microscope is used with a cinematograph apparatus, we are able to record the motion of infinitesimal forms of life or energy which have hitherto been invisible.

We can perceive in a small piece of earth or in a drop of water extraordinarily minute vegetables belonging to a new and mysterious kingdom of life, and possessing every external attribute of an animal, such as the power of moving about and the power of feeding on other forms of life. We are able to trace in particles of matter, visible only through the ultra-microscope, strange motions, like those of a swarm of dancing gnats, hopping and jumping about together, and flying apart with astonishing rapidity; and in other varieties of matter we can distinguish strange processes of growth.

But the microscope humbles the pride of the human intellect, while extending the power of human vision. It penetrates beneath every simple surface of things to an underlying complexity, strange, marvelous, and awe-inspiring. When the microscope was still very imperfect, Huxley and Tyndall thought they discovered the secret of life in protoplasm, but a few improvements in the manufacture of glass for microscopic lenses revealed that there was much more in the simplest of cells than protoplasm, and, moreover, showed what complicated processes take place within the simplest cell. The field of knowledge is immeasurable, yet at each magnification of our powers of sight our field of vision widens. That is why microscopic science is so alluring. Take just one corner of it — microbe study; scarcely a thousandth part of the work required to be done there has yet been performed, so complicated, so varied, so enigmatical are the tiny shapes of life whose territory we are beginning to explore.

The modern microscope is one of the newest instruments of science. The true principles of it were not generally known by actual experiment until about 1818, when a noted German physicist, Professor Ernst Abbe (1840–1905), induced a German glass-maker, Dr. Otto Schott, to work with him in manufacturing a new kind of lens. Abbe, who had been studying the problem of optics since 1873, overthrew many of the theories of the microscope formed by his predecessors. He discovered what a microscope could be made to do, and he made it do it. He fixed the uttermost limits of vision of the marvelous artificial eye, and the recent instruments constructed in accordance with his ideas by Carl Zeiss of Jena and Bausch & Lomb in America, seem now to have reached those limits.

From the burning glass, via the spectacles to the microscope

The earliest extant example of a magnifying glass is the crystal found by Layard in his excavations of Nineveh. It is twenty-six hundred years old and consists of a piece of rock crystal, oval in shape and convex on one side, about a fifth of an inch thick, an inch and two-fifths in diameter, with a focal length of about four inches. It is now in the British Museum. Whether or not the Greeks and Romans were familiar with magnifying glasses is a matter of discussion, but it seems probable, especially in view of the delicate engraving on many of their intaglio gems, that some form of lens was used by them to aid the eye. They could hardly have failed to have their attention called to the action of spherical glass vessels filled with water or the magnifying effect of the burning glass, known to have been used in the time of Socrates. The Arabians, too, in the eleventh century seem to have known something about the optical qualities of convex crystals, and it was possibly from them that Roger Bacon obtained his idea of making objects appear larger. With these lenses, he says, there could be devised "an instrument useful to old men and to those whose sight is weakened, for by means of it they would be able to see letters however small they are, made large and clear." It was in 1280, however, that an Italian, Salvino degli Armati of Florence, first brought out a pair of glasses in the form of spectacles. This is now the commonest form of the simple microscope — two magnifying glasses fitted in a frame so as to be used before the eyes, and it was left to two spectacle-makers, Hans and Zacharias Janssen, of Middleburg, Holland, who undoubtedly invented the telescope, by a simple modification in it to produce the compound microscope in 1590.

In its simplest form the microscope is an artificial lens, acting in the same way as the crystalline lens of the eye. As is now well known, the path of a ray of light is affected by the density of the transparent medium through which it passes. A simple experiment will show this. Fill a tumbler full of water, which is denser than air, and put an ordinary long lead pencil into it, and then look sideways at the pencil as it rests partly on the edge of the glass and partly in the water. The part of the pencil which rests in the water will seem to be broken off from the part that remains above in the air.

What happens is this: the rays of light, by means of which we see the pencil, are bent inwards when they enter the water. If we took a little glass globe and filled it with water, and then sealed it up, the water would bend all the rays of light that entered it. The rays would all be bent inward toward each other and would finally meet together at a certain point.

All that was required to discover the principle of magnifying glasses, spectacles, telescopes and microscopes was the knowledge that the curved surface of a globe of glass and water bends inward a ray of light, for the reason that glass and water form a denser medium than air. When this was found out, it was fairly easy to begin experimenting with various kinds

THE SCALES IN A SPECK OF DUST FROM THE WING OF A MOTH

Seneca, the learned tutor of the infamous Roman emperor Nero, noticed that if a glass globe was filled with water and placed on a written page, the letters would appear much larger than they really were; but no man in Europe, until the days of Roger Bacon, tried to understand *why* a globe full of water should magnify the objects behind it.

It is from this kind of intelligent search into the causes of natural phenomena that modern science was born.

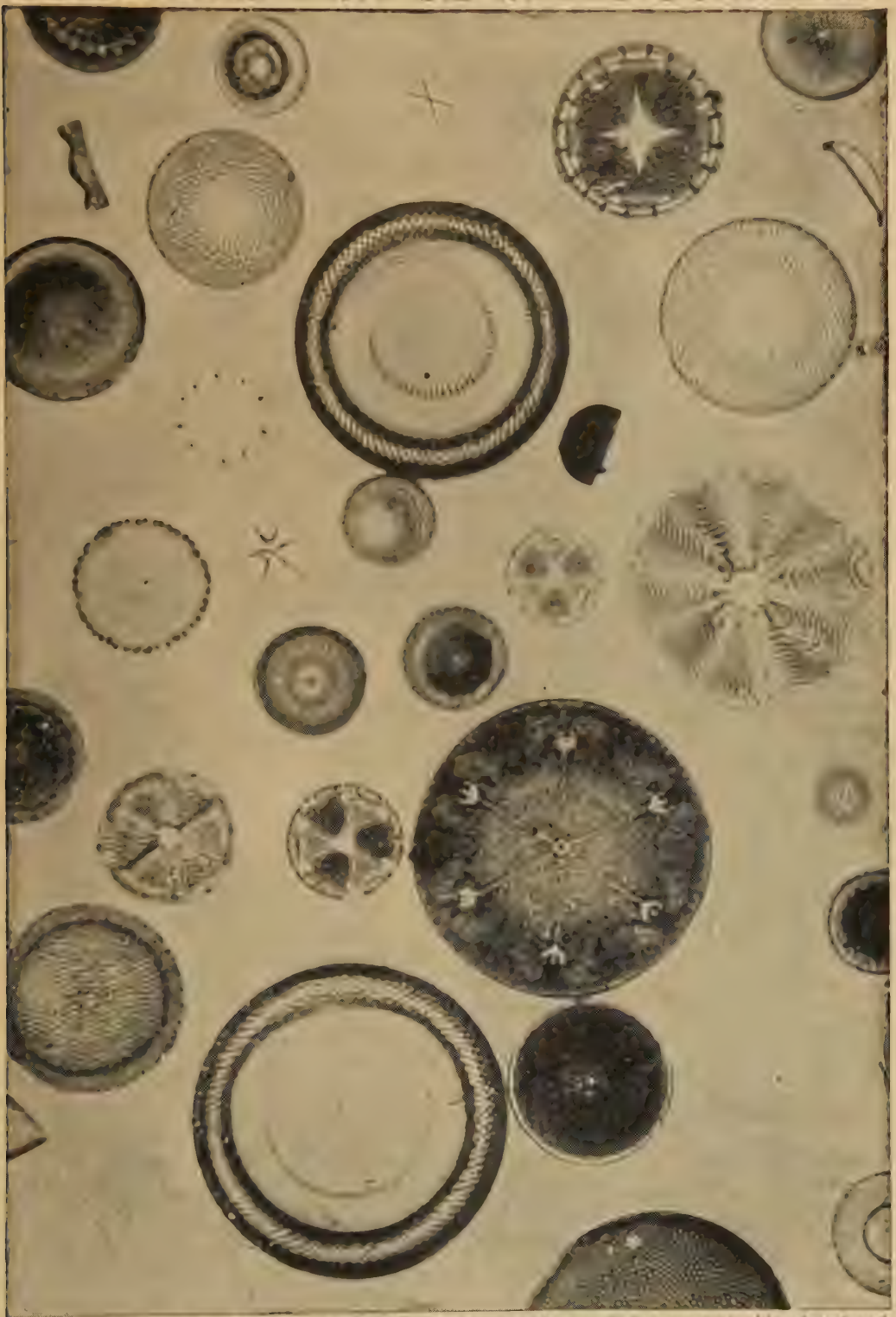
of glass with different surfaces. This was done by some of the earliest spectacle-makers. They discovered that a convex surface, in which the smooth glass bulged outward, bent the rays of light inward; while a concave surface, in which the glass bulged inward, bent the rays outward. From this they worked out in practice a series of convex spectacle glasses for people suffering from long sight, and a series of concave spectacle glasses which remedied the defects of short sight.

We are in the happy position of understanding more about the matter than the Italians who amazed Europe in the thirteenth century by their "magic" glasses which improved the human sight, for we know more about the human eye than the old spectacle-makers. A principal thing in the human eye is the crystalline lens. It is composed of perfectly transparent fibers, and has two rounded or convex surfaces like an ordinary magnifying glass. At some distance behind the lens is a transparent film of very sensitive nerves. This is the retina. It forms a screen at the back of the cavity of the eyeball, and it is coated behind with a dark colored matter.

Now, suppose we are looking at this page. It is flooded with light which it reflects much as a mirror does. The rays of reflected light spread out, and a certain number enter the pupils of our eyes. For convenience let us examine what takes place in the lens of one eye. As this lens has a convex surface, it bends the rays of light inward, bringing them together. The page at which we are looking is, of course, much larger than the little dark screen at the back of our eye, but the rays of light are so brought together in passing through the lens that when they strike on the dark screen they form a much-reduced image of the page.

THE HEAD AND SHOULDERS OF THE COMMON FLEA

DUST-SHELLS THAT LIE IN THE OCEAN BED



Diatoms are minute sea-plants, consisting of protoplasm with a shell on each side of it, found in immense numbers in the sea, but so small that here they have been magnified 60,000 times.

THE TONGUE OF A CRICKET

THE FOOT OF A MOLE CRICKET

ANTENNÆ OF A COCKCHAFER

THE STING OF A WASP

Thus the eye is a microscope, and attached to it is an exquisite piece of mechanism by which it is adjusted. Around the window or pupil of the eye is a kind of colored curtain — gray, brown, black or blue; this contracts and partly closes the window when the light is too strong, and expands and leaves a large opening when the light is weak. More important, from our present point of view, is the muscle of the eye, which is called the ciliary muscle. It presses on the top and on the bottom of the lens. In practically all perfect eyes the lens is flatter in front than behind. But when we look at very near things this flattish front is useless. We need a more microscopic vision, and the ciliary muscle at once gives us this, without any conscious effort on our part. The muscle contracts, and allows the lens to bulge out slightly in front and form a convex surface, like the surface of a magnifying glass. Our eye instantly acquires a stronger magnifying power, the rays of light are brought to the proper point at the back of the eyeball, and a clear image is formed of the object near at hand.

Often, when persons are growing old, the lenses of their eyes grow too flat in front; so they have to use a pair of spectacles with convex glasses when they want to see very near objects. On the other hand, people who are constantly poring over books, or using their eyes in other ways for the study of minute objects, suffer from the opposite defect. Their natural vision is excellent at a very short distance. Their eyes, however, cannot bring to a point the rays of light from distant objects, so a very indistinct and misty image of these objects is formed on the screen at the back of the eyeball. If we look at the glasses worn by short-sighted persons we shall find that they are hollowed out, or concave. The concave surface bends outward all the rays of light that pass through them; it makes them diverge, and thus corrects the too convex surface of the lens of the eye, and helps to bring the rays to the proper focus. The time comes in advanced old age when the limit of such help is reached, and no higher powered lenses avail to relieve the difficulty of vision.

The word "focus" meant originally a fireplace. If a magnifying glass be held in a strong sunlight, it will bend the rays of light and make them meet in a small circle a little distance away from the back of the lens. The spot at which the rays meet will actually become a fireplace if a piece of paper or other inflammable material is held there. When the glass is used only for magnifying purposes, the focus is at the spot at which the rays bent by the glass meet and form a little picture of the object. This little picture is called the image. In the earliest and simplest of compound microscopes, a magnifying glass was inserted at the end of a tube, and the tube was six feet long. Another lens was inserted at the opposite end to serve as an eyepiece.

When the microscope was pointed at a small object, the first magnifying glass collected the rays of light, and bent them, and sent them through the tube in a kind of narrowing stream of rays. All the rays met at the focus, and created an image in a certain part of the tube; and if the eye had been put there, the image could have been seen. Nothing, however, was placed at the spot where the rays met, so they crossed each other, and diverged again in a broadening stream. In this way they carried the image to the second lens, or eyepiece. This was also a magnifying glass, and it collected the broadening stream of rays, and again bent them and sent them towards the eye of the observer. Thus there were two processes of magnification.

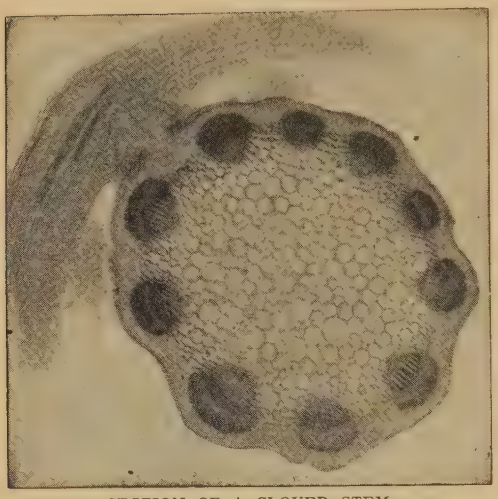
Such were the most primitive of compound microscopes; and the principle on which they were built is practically the same as that employed in the most powerful of modern instruments. There are two systems of lenses. One is placed at that end of the tube which is directed on to the object that is to be examined. This system of lenses is called the objective. At the other end of the tube, where the eye of the observer is placed, is a second set of lenses, which is termed the eyepiece. The objective is the most expensive and the most powerful part of the microscope. It often costs as much as $150.

THE MOUTH OF A TADPOLE

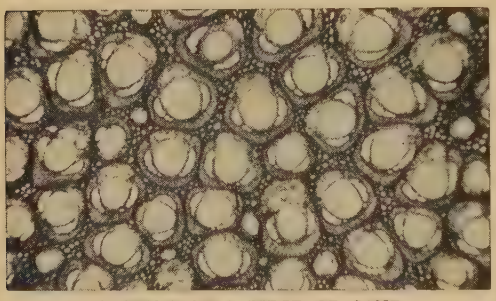
LANCES OF A BLOW-FLY

THE CLAW OF A MOLE CRICKET

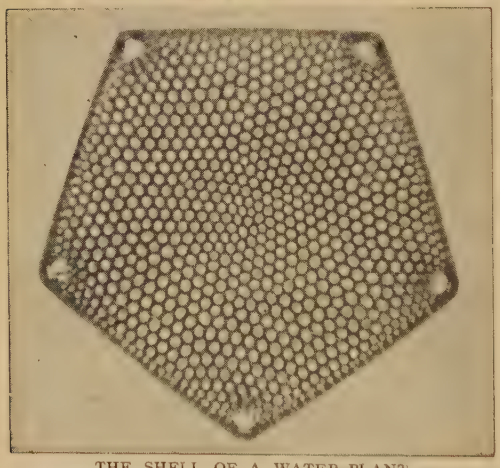
THE FOOT OF A WATER-BEETLE



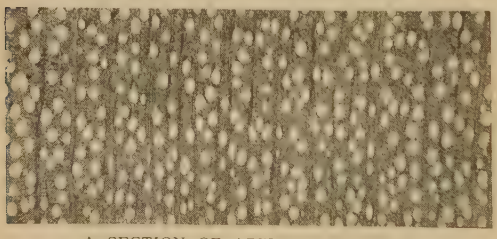
SECTION OF A CLOVER STEM



SECTION OF A PIECE OF CANE



THE SHELL OF A WATER-PLANT



A SECTION OF APPLE-TREE WOOD

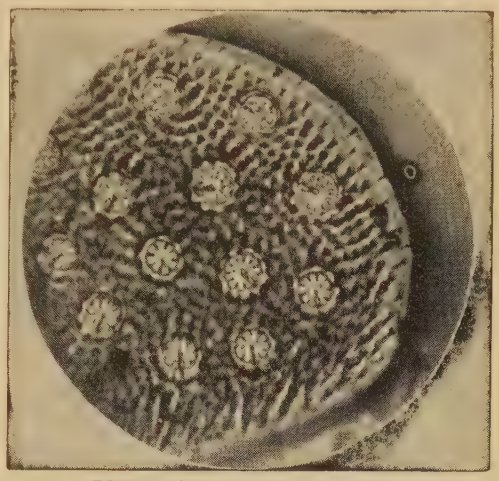
About six objectives are required with a first-rate microscope. They are detachable, and of varying powers and properties, and their use depends on the kind of work that is wanted, and the kind of object that is being studied. The objective collects the rays of light which come from an object; it bends these rays inward, and sends them in a narrowing stream through the tube to the spot where they form an image. Here they again part and travel to the eyepiece, where the image is still further magnified, and transmitted to the eye of the observer.

In all microscopes of this kind, only one eye can be used. This is very fatiguing. Microscopic study is indeed the most laborious of all scientific pursuits. The physical strain of long-continued investigation, carried on with the highest powered lenses, is very great, and there is combined with it an incessant mental effort. Happily, F. H. Wenham discovered in 1860 a new way of arranging the microscope, which makes its use less wearisome. He designed a microscope with two tubes and two eyepieces. The right-hand tube was straight and fitted with an objective; the left-hand tube was fitted into the side of the main tube. When the stream of light-rays passed through the lenses of the objective, and emerged into the main tube, they struck against a prism. This was a piece of glass so shaped that it divided the stream of light-rays into two portions. The left portion passed uninterruptedly through the main right-hand tube, and so to the right eye of the observer; the right was reflected first to one side of the prism, and then to the opposite side; thence it was directed into the left tube of the instrument, along which it traveled to the corresponding eye of the observer. In this manner there were produced two images of the one object lying beneath the objective.

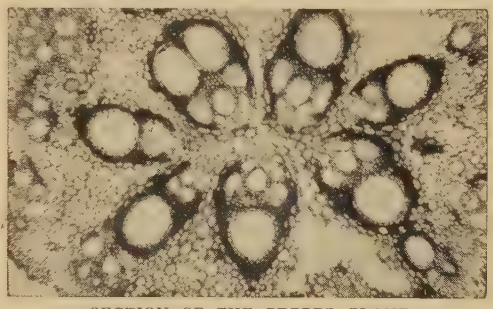
And now we come to a simple technical point which we hope will illuminate the explanation already given of the action of the compound microscope. There were two images in the Wenham's binocular microscope—one image in the right tube, and one in the left. Both these images,

it must clearly be understood, were invisible images. They could only be seen by placing two pieces of paper at those spots in the two tubes where the two divided streams of light-rays separately came to a focus. Naturally, the two tubes differed in length, the eyepiece of the left-hand side tube being farther away from the object than was the eyepiece of the straight main tube. This produced a curious effect. The rays in the side tube had to travel farther, after they had formed an image at the focus and had there crossed and spread out again. In thus traveling, they spread out more, and the result was that they produced in the left eyepiece a more magnified second image than that which the shorter rays produced in the right eyepiece. This disagreement, however, was easily corrected by making the lenses in the left eyepiece lower in magnifying power than those in the right eyepiece.

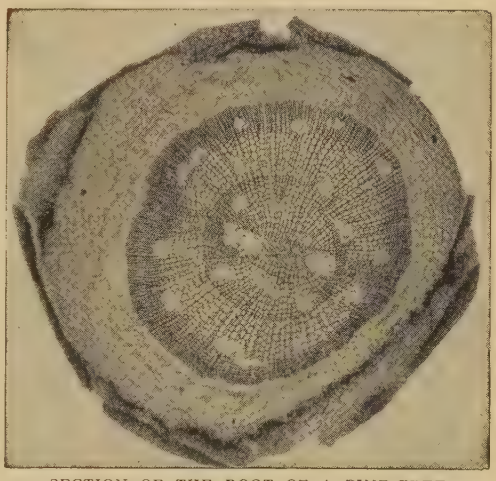
This type of microscope, however, failed to meet general approval as there was one defect which made it objectionable for long continued use. Its convergent tubes, causing the two images to reach the eyes at an appreciable angle, introduced a severe strain on the eyes when the instrument was used for long periods, and research workers, while recognizing the real value of binocular vision through the microscope, were nevertheless forced to discontinue using it. In recent years an improvement was effected and a binocular microscope was introduced by Leitz of Germany and later by Bausch & Lomb in the United States in which the tube length is identical for both eyes when set for normal vision, and the eye-tubes are parallel. In addition a screw thread allows a slight modification of the tube length on one side to compensate for any possible variation in visual acuity of the observer. An adjustment is also provided for interpupillary distance so that the maximum impression of roundness and depth in the object can be secured. At present a large number of research men in various fields of science are using the binocular microscope with marked success and its use is increasing.



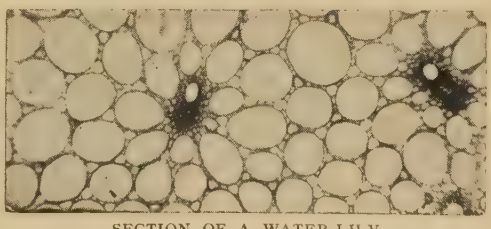
TERMINAL SEGMENT OF A FLEA



SECTION OF THE PEPPER PLANT

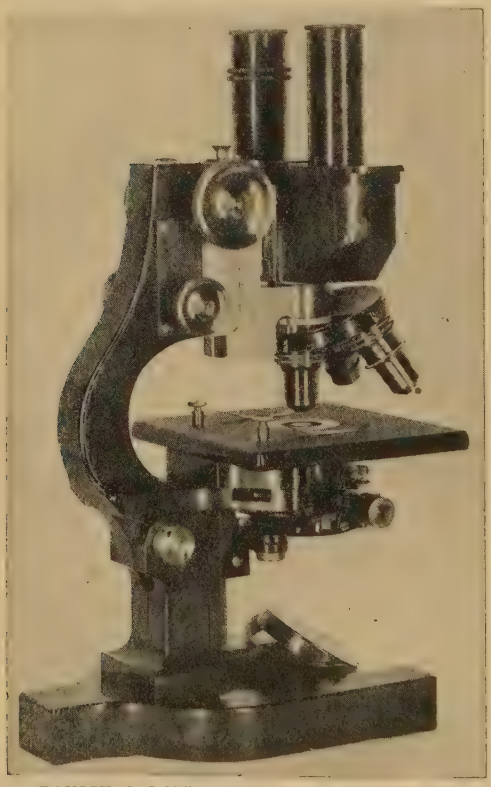


SECTION OF THE ROOT OF A PINE-TREE



SECTION OF A WATER-LILY

It may be safely predicted that the binocular microscope will continue to grow in popularity to the final exclusion of the single body type. Binocular instruments are not only more restful than monocular but they have some very valuable properties. They can give what is called a stereoscopic vision. A simple experiment will explain what this is. Set upright on a table a thin book about an inch thick and five inches in width. The back of the book, where the title is usually

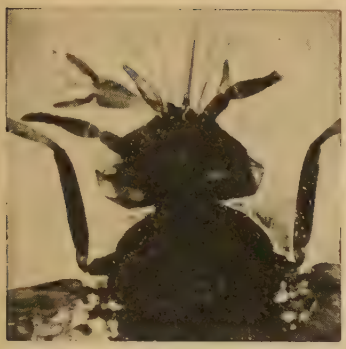


BAUSCH & LOMB BINOCULAR MICROSCOPE

stamped, must face the observer, and be in an exact line with his nose, at a distance of about eighteen inches. Each eye will now be able to see a different side of the book; the right eye the right side, and the left eye the left side. When both eyes are simultaneously employed, the book appears to be solid, and to have depth. No confusion arises in the mind of the observer through the blending of two images of the same object, taken from two different standpoints. The same effect of depth is produced in the stereoscope, where two photographs, taken from slightly different angles, are simultaneously viewed through the instrument. The depth dimensions are revealed in a wonderfully vivid and distinct manner. By means of the binocular microscope in which this stereoscopic vision is obtained, we are able to examine the structure of minute living objects with perfect ease.

The early microscopes had two grave faults, which made them useless in the finest sort of work. One of these defects is called spherical aberration. As a lens has a curved surface, it is thicker in the middle and thinner at the edges if it is a convex lens, and thicker at the edges and thinner in the middle if it is a hollow concave glass. Let us take the case of a convex lens, with a stream of light-rays falling on its entire surface. The light-rays that pass through the thin edges will be bent in a different degree from those that pass through the thick bulging glass in the middle. Thus the rays will follow different paths, when they emerge from the glass, and they will not meet in a focus. That is to say, they will not produce an image, but only a wild and useless distortion of the object which it is vainly wished to magnify. So, before the compound microscope becomes of any practical use, this spherical aberration has to be corrected. Another lens of a different shape is fitted to the uncorrected lens, in such a way that all the rays are brought to the same focus. For example, a convex lens with two bulging curves has adjusted to it a glass one side of which is flat, and the other side of which is concave so that it fits exactly on to one of the convex surfaces of the uncorrected lens.

This, however, leads to another grave defect, which for many years was regarded as irremediable. Here we arrive at the fundamental realities of the science of the microscope. Hitherto, for the sake of simplicity, we have been talking about streams of light-rays. We have pretended that a light-ray was a simple, definite thing. But, as a matter of fact, white light, as is now generally known, is formed of a series of waves in the ether, and these waves are of very different lengths.



THE HEAD OF A GADFLY

ANTENNÆ OF A MOTH

THE TONGUE OF A MASON-BEE

When a ray of light passes through a three-sided piece of glass, the different waves are separated; and when they emerge from the three-sided glass and fall against the screen, they form a band of rainbow colors. The same thing happens when they pass through any kind of lens, concave convex and so on. The white light is decomposed into a series of colors—violet, indigo, blue, green, yellow, orange and red. Each of these colors is separated from the other, and each makes a faint image of the object which is being magnified by the lens. This is called chromatic aberration.

The problem was to bring all the colored images together at one focus. Only by this means could the compound microscope be developed into a perfect instrument of scientific research. What was wanted was a variety of glasses of different densities, but, after about a hundred years of search, only two kinds of glasses could be discovered. These were crown and flint glasses. Flint glass is slightly denser than crown glass, and it has more dispersive power.

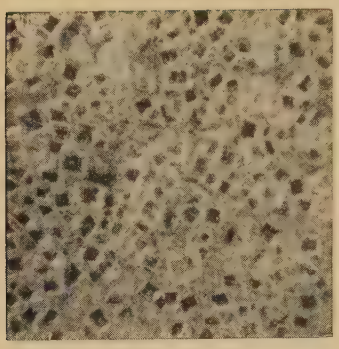
When this fact was understood, it became possible to correct two colors, by making a lens partly of flint glass and partly of crown glass. A piece of flint glass was ground hollow on one side, and made flat and straight on the other side: a lens of this shape is called plano-concave. A piece of crown glass was then made into an ordinary convex lens, with two bulging surfaces. The lower surface fitted exactly into the hollow space in the flint lens, and by cementing it in this position there was formed a doublet lens. The flat flint surface was placed above the object required to be magnified.

The light-waves coming from the object passed through the flint glass, and were, of course, broken into waves of colored light, each stream of colored waves being bent differently. A wave of red light is much longer than a wave of violet light, so the shorter violet wave was affected most. The various streams of colored light emerged, widely scattered, from the flint glass, and entered the crown glass, and here their paths were again once more altered.

THE EGGS OF A MOTH

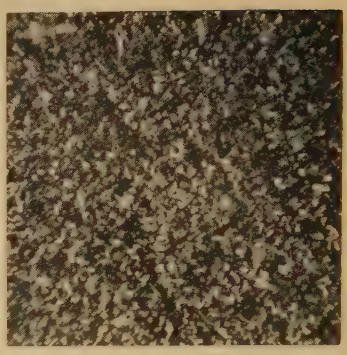
THE EYE OF A COCKCHAFER

THE TONGUE OF A FANTAIL FLY



CRYSTALS OF SALT

THE EDGE OF A KNIFE



DUST ON A SHELF

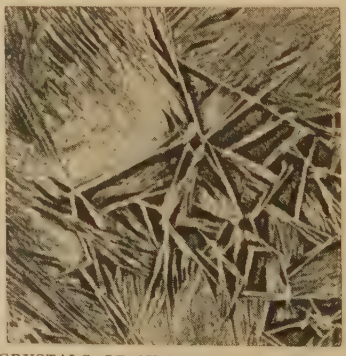
The result was that two streams of colored waves were at last bent somewhat in the same direction, and when they came to a focus they formed a two-colored image. The other streams of light-waves formed a series of fainter images, which were not only useless, but very confusing. Microscopes — called achromatic — were made that blocked out all the unfocused images, and left only the double-colored image to be transmitted to the eyepiece, and even this image was not free from defects.

So the matter remained until Professor Ernst Abbe, of Jena, and Dr. Otto Schott obtained from the German government a subsidy, and began a series of very important researches with a view to discovering new kinds of glass with just the density required to bring all the various colored waves of light to the same focus. The work of research lasted several years, and in 1886 the new microscope was put on the market. Not only did it contain a new glass, fluor glass, but it embodied some new and absolutely vital principles of optical construction at which Abbe had been working since 1873.

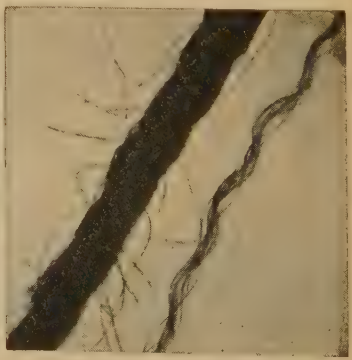
He was, in fact, the father of the modern microscope of extremely high power. He created a profound revolution in the mathematical theory of the instrument, and he worked out his theory on paper with such correctness that he was able to show exactly what the microscope could be made to do. He knew exactly what densities and curved surfaces were needed long before the things he wanted were discovered. Thus he was able to give directions to the men who worked with him at the practical part of the business. They had only to follow the lines of research he had worked out by mathematics. Abbe never claimed the subsidy offered by the government, for his plan of research was so well laid that the discoveries were effected before the money was needed.

The firm of opticians Zeiss & Co., of Jena, of which Professor Abbe became the head, has within recent years discovered a way to make use of the varying lengths of light-waves, instead of reducing them to a uniform focus. Red waves are about one-30,000th, while violet waves are only one-60,000th, of an inch in length.

THE BUD OF A LILY



CRYSTALS OF NITRATE OF POTASH



SEWING-COTTON AND FINE SILK

Wonderful adaptation of the microscope to the varying length of light rays

Now by means of the shorter violet waves objects can be distinguished which are twice as small as those which can be distinguished by the long red waves. The mean wave-length of light is one-47,000th of an inch, so that if the shorter violet wave could be used it would enable an observer clearly to distinguish minute things which, if viewed through the most powerful of microscopes in ordinary light, would only appear blurred together. Naturally, the shorter the light-wave which falls on anything and then bounds back from it, the more detail the wave will carry to the eye. This was clearly seen when a microscope was invented to be used only with violet light. Infinitesimal markings below the range of the wave-length of ordinary light were clearly perceived with lenses especially shaped and constructed to deal with light-waves only one-60,000th of an inch in length.

But, as is well known, there are very much shorter waves of light than the shortest of the violet. The ultra-violet light, however, is not visible to human eyes. Its waves are too short to make any effect on the dark screen at the back of our eyeball. What added to the difficulty was the fact that no known kind of glass was capable of being used to bend ultra-violet light in the way that ordinary light is bent by lenses made from crown and flint glass.

The latest advance in the construction of microscopes

However, the Zeiss firm resumed its experiments, and succeeded at last in making lenses out of molten quartz. By means of these quartz lenses there was constructed a microscope which could be used with ultra-violet light. The image produced in the quartz eyepiece of the microscope was, of course, invisible to the human eye. Thus it was impossible for the observer to focus the lenses, so as to obtain an exact definition of the objects, which were sometimes one-240,000th of an inch in size. But by an ingenious arrangement this difficulty was overcome. The invisible image was projected from the eyepiece against a special screen, and on this it produced an image by the chemical action of the ultra-violet light. The microscope was then adjusted so as to give as much brilliancy as possible to the image, and a photographic camera was attached to the eyepiece, and a photograph was taken on a plate which had been made sensitive to ultra-violet light.

The microscope for ultra-violet light represents the ultimate advance practicable on Abbe's theory of the limits of the powers of the microscope. It is very important, however, to get a clear and definite idea of what this limit is. There is no practical limit to the magnifying power of a modern microscope. If a single dot, of any size whatever, is placed beneath the objective of a first-rate instrument, that dot will be magnified so that the eye can perceive it. There is a very minute animal called a rotifer, which is found in great numbers in ponds. Some kinds of rotifers are invisible to the naked eye. If, however, a man cared to go to a great and useless expense, he could probably have made a microscope which would magnify one of these rotifers to the size of a windmill. It would, however, look like a windmill in a thick mist. Little or none of the exquisite detail of the rotifer would be perceived — one would, indeed, scarcely be able to make out whether it was a windmill with whirling sails, or an animal surrounded with revolving organs.

The power that is much more important than magnification

There is something more important than magnification. This important thing is called "resolution". Supposing two lines are drawn so close together that one hundred thousand of them would only occupy one inch. A microscope that would "resolve" those two lines in ordinary light, that would make them stand away from each other so that they could be clearly seen, would be a microscope of very remarkable power. In fact, the resolution of lines ruled a hundred thousand to the inch is a power possessed only by the very best of modern microscopes.

In this respect a microscope can be compared with a telescope. If a good telescope is pointed at a distant star, it makes it seem smaller; if the finest telescope in the world is pointed at the same star, it makes it appear still smaller; and sometimes it makes it appear so small that the star is resolved into two minute points of light. The two minute points of light are the reality. It is a double star, and the stars are so close together, and at such a vast distance from our earth, that only an instrument of tremendous power can disentangle them from each other, and get a separate image of them.

New wonders of microscopy that are on the eve of discovery

And now we come to the achievement of the impossible — the ultra-microscope. One of the smallest known pieces of matter existing as a distinct thing is a molecule of hydrogen. For a long time chemists have vainly been endeavoring to study matter in its molecular state, but it now seems likely that a new kind of microscope will enable them to do this. It is a good many years ago since Tyndall, following out an idea of Faraday, came near to accomplishing an apparent miracle. He used an ordinary kind of microscope, inferior to the best now obtainable, but he employed a new and curious kind of light. Tyndall was, we believe, the first man to discover why the sky is blue. He found that its blueness was due to the fact that the waves of light from the sun struck against very minute particles in the air, and became what is known as "polarized light".

This gave him the idea of using light in such a way as to reveal invisible particles of matter. By the use of Tyndall's method Dr. H. Siedentopf and Richard Zsigmondy, of Göttingen, have evolved the ultra-microscope. A small and extraordinarily intense beam of electric light is directed against the objects which it is wished to see. The waves of light strike against the objects and rebound, and are bent out of their path. They fly away in all directions, and some of them enter the lens of the microscope placed close above, and from the lens they are sent to the eyepiece. All that is really required of the particles against which the light-waves strike is that they should be capable of reflecting light.

How the cinematograph may help the future disclosures of science

An erroneous idea in connection with the ultra-microscope seems to be that particles which will not show detail, or be "resolved", under the ordinary microscope, will do so under the ultra-microscope. The fact is that the light which is diffracted from the small particles in suspension in the fluid under examination serves only to indicate the presence and location of the particle in relation to other particles rather than its size. For example, fluids in which very finely divided metallic particles are suspended so thoroughly that they do not precipitate even after long standing, are called "colloids". When such a colloid is examined under the ultra-microscope, it is seen that the metallic particles exhibit certain characteristic motions both in relation to the fluid and to surrounding particles. They are usually found to be in more or less rapid motion and the effect is often very beautiful. Their behavior in relation to each other seems to follow in a general way the relations existing between the planets in our solar system and others which we know through the telescope, from which we derive the name "cosmic" or "planetary" movement to describe their action. This opens up a fascinating field of philosophical speculation much too involved to enter at this time.

The study of the action of ultra-microscopic particles is becoming important in industrial lines, and the results obtained are working out to the benefit of mankind. The methods of this science have already been applied in the study of oils, asphalt, paints, photographic emulsions and numerous other things which are of immense importance in our daily lives. As an understanding of ultra-microscopy increases we may expect decided advances in our knowledge of those things upon which we depend for our pleasure and comfort.

TRADE AND THE ROAD

How Railways, the Life of Modern Land Commerce, Have Changed the Face of Civilization

THE ILLIMITABLE HOPES OF PROGRESS

COMMERCE has ever been dependent upon such roads as the engineers could make for it. We have seen how the sea has been made available for man. The great waters either divide or connect the peoples of the world. Without science, they divide and divorce; with the aid of science they connect and marry. We pass from the high seas to the consideration of the equally important tracts and highways with which man has covered with a network the land area of the globe.

Civilization and the road have always gone together. The wonderful engineering works of the Romans still exist, and will remain while man remains upon the earth, a tribute to the wisdom as well as to the courage of their constructors. It was the Roman road which largely helped to sustain Roman power during so many wonderful centuries. It is the glorified road of modern science which has given mankind a new mastery of the world, and which, in combination with the exercise of similar powers upon the seas, has given a new meaning to the word "Commerce".

Indeed, when all is said as to the work of men in other fields, it is the engineer and the scientist who stand out as the preëminent re-builders and re-creators of civilization. The arms of the soldier, the deep thinking of the philosopher, the lofty aims of the statesman, are all alike subsidiary to the forces invoked and yoked by science. The methods of warfare and the nature of campaigns are revised, the food for thought is sown, the possibilities before the statesman are changed in kind and direction by the new control of nature which is the gift of science to the world. The commerce of the eighteenth century is an idle tale in comparison with the gigantic interchange of commodities which has become an unrealized commonplace in the twentieth century.

And there is a very important distinction to be drawn between the old commerce that existed before the modern scientific era and the new commerce of our time. It is that, before power had been harnessed by the engineer, the methods of commerce were far ahead of the means of prosecuting it, whereas today the very reverse is the truth. The present position is that the machinery of transmission, the power to transport commodities, whether by land or sea, is superior to commercial methods.

We have already noted the intimate connection between the mining of coal and the great inventions which revolutionized industry, commerce and the world. The steam engine was devised without conception of what it would do for industry. The immediate purpose was to pump water out of our mines to enable men to get at their precious coal. Similarly, the locomotive was invented without conception of what it would do for the world. Those who worked at it were chiefly mining engineers, faced with the difficulty of hauling that bulky and weighty substance, coal. Trevethick and Stephenson were both intimately connected with mining operations.

It is exceedingly difficult, in looking back upon the origin of certain inventions, to decide the real degree of genius possessed by their originators. The connection of even moderately ingenious minds with a great necessity is bound to produce effective results.

Genius of inventions usually judged by the magnitude of their results

The probability is that very many thousands of latter-day minor inventions demand fully as much, if not more, skill and ingenuity than a number of the primary inventions, such as the conception of movable type, or the use of a smooth rail for traction, or the idea of the piston, or of the multi-tubular boiler, or the cotton gin — all of them ideas of a very simple order. We are naturally apt to glorify the character of an invention by the magnitude of its results, and some of the simplest inventions have had enormous ones.

George Stephenson took the elementary locomotive of Trevethick (1800) and made it very much the steam locomotive that we know today, but which we shall not know very much longer. For the steam locomotive is already destined to become obsolete, although necessarily its disappearance is likely to be very gradual. With Stephenson's perfecting of the steam locomotive, the railroad began its triumphant career. The competition in which Stephenson's "Rocket" was victorious took place when nearly one-third of the nineteenth century had already elapsed. That is to say, the history of modern railroads is not yet quite a century old. Think what marvels have been accomplished in that brief fraction of the world's recorded history!

The first passenger railroad was the Stockton-Darlington line, which was opened in 1825. Then came the Liverpool & Manchester, opened in 1830. Continental nations were quick to see what a mighty thing had been discovered. In 1833 France, and in 1835 Germany, entered upon similar schemes. Belgium employed George Stephenson himself upon government lines.

The relation of Oliver Evans to the development of the locomotive in the United States is not unlike Trevethick's position in British railway history. Evans introduced the non-condensing high-pressure steam engine, which under favorable conditions might have been developed into a successful locomotive. In 1812, in a letter to *Niles' Register*, he gave an account of his activities, and said that in 1804 he had propelled his dredging machine through the streets of Philadelphia. This was a scow with a five-horse-power engine for raising mud into flat boats. He added wheels and a paddle wheel, and propelled it to the Schuylkill, thence to the Delaware, and up the Delaware to the city. When this amphibious machine, the *Oruktor Amphibolis*, was criticized as too slow, he offered to construct a steam carriage which would defeat the fastest horses. He added:

"When we reflect upon the obstinate opposition that has been made by the majority to every step towards improvement; from bad roads to turnpikes; from turnpikes to canal, from canal to railways for horsed carriages, it is too much to expect the monstrous leap from bad roads to railways for steam carriages, at once. One step in a generation is all we can hope for. If the present shall adopt canals, the next may try the railways with horses, and the third generation use the steam carriage. I do verily believe that the time will come when carriages propelled by steam will be in general use, as well for the transportation of passengers as goods, travel at the rate of fifteen miles an hour, or 300 miles per day."

A genius of a different type was that of John Stevens, of Hoboken, the "father of the American railroad". In 1810 Stevens applied to the legislature of New Jersey for the first American railway charter. He urged upon the state of New York that it should construct a railway instead of a canal. His idea was that the railway might be built on timbers supported on brick pillars three to six feet above the ground, thus elevated to avoid the snow and to prevent decay. The rails were to be of bar iron. In 1820 he constructed at his own expense a short experimental railroad at Hoboken. Finally, in 1823, Stevens and his associates secured the grant of a charter for a railroad from Philadelphia to Columbia. Lack of confidence on the part of capitalists prevented its construction, and in 1826 the charter was repealed.

The importance of tramways in connection with the development of railroads has already been mentioned. Tramways were used in England for carrying coal as early as 1630. The rails were first of wood, then of cast iron, and then of wrought iron. At first the flanges were attached to the rails. Not until 1789 were the wheels themselves flanged. The gage of these old tramways, over all, was usually five feet, so that they could take the ordinary wagons of that day. Allowing for two rails, each $1\frac{3}{4}$ inches wide (the usual width), gives four feet eight and one-half inches, which was the gage used on Stevens's roads and which is today the standard gage used in the United States. In the United States, tramways were built as early as 1807, and possibly earlier. A famous old tramway at the granite quarries at Quincy, Massachusetts, built in 1823, enjoys in popular tradition the reputation of being the "first American railroad". As a matter of fact, it was by no means the first of the tramways.

More like modern railways were the lines built to supplement water transportation, as, for example, the ship railroad from Hollidaysburg to Johnstown, Pennsylvania, the Mauch Chunk extension of the Lehigh Canal, and the Delaware & Hudson Canal Company's tramway from Carbondale to Honesdale. The cars on these primitive roads might be propelled by horses, by stationary engines and even, on occasion, by sails! It was on this last line that the locomotive *Stourbridge Lion*, imported from England, was tried out in 1829, but it was found to be too heavy for the crude track of wood stringers and half-inch bars, and to improve the track was too expensive.

The Baltimore & Ohio, which was the first American trunk line, was chartered in 1827, and construction was begun in 1828. The Mohawk & Hudson, the germ of the future great New York Central system, was opened from Albany to Schenectady in 1831. The Charleston & Hamburg Railway was chartered by South Carolina in 1837, but its promoters had no very clear plans and worked in secret because they were fearful of ridicule.

They built a short bit of experimental track in Charleston, on which a mule easily drew a car with 47 bales of cotton. Given courage by the mule's extraordinary showing, the projectors took steps to begin construction. In 1830, when some of the track had been laid, the first train, made up of four-wheeled cars carrying 13 passengers and 3 tons of freight, propelled by a sail rigged on a mast, sped on its way at 15 miles an hour. In Massachusetts, three lines of railway radiating from Boston to the cities of Lowell, Worcester and Providence were in operation by 1840.

A PICTURE OF WORLD DEVELOPMENT

The Railways of Important Countries

Country	1850	1870	1890	1924*
	Miles	Miles	Miles	Miles
Europe				
United Kingdom	6,621	15,537	20,073	23,734
Germany	3,637	11,729	25,411	35,209
France	1,714	11,142	22,911	33,568
Russia	310	7,098	18,059	42,504
Italy	265	3,825	7,983	12,885
Austria-Hungary	954	5,947	16,490	4,125
Switzerland	15	885	2,014	3,586
Belgium	554	1,799	2,810	5,841
Holland	110	874	1,621	2,380
Norway		224	970	2,141
Denmark	20	470	1,217	6,818
Spain	17	3,400	6,070	9,842
North America				
United States	9,021	52,922	166,654	262,482
Canada	66	2,617	13,256	39,771
Newfoundland			112	904
Mexico		215	6,037	16,442
Asia				
India		4,775	16,345	37,265
Japan			1,139	8,475
China			80	6,818
Africa				
Egypt		742	961	3,065
Union of South Africa			2,046	10,890
Rhodesia				2,468
Algiers and Tunis			1,927	4,009
Belgian Congo				
South America				
Argentina		637	5,434	21,935
Brazil		504	6,135	17,907
Chile		452	1,682	5,102
Peru		247	933	1,997
Uruguay		61	953	1,660
Australasia				
Australia		953	9,524	26,202
New Zealand		46	1,956	3,156

* In a few cases the figures in this column are for 1923 and 1922, the latest available years.

By 1840 the United Kingdom had 1800 miles of railway, but the United States had forged ahead with 2800 miles. As for the rest of the world at that time, Germany had about 300 miles, Belgium 200, Holland 10, Italy 13 and there the list almost ends. Ten years later, however, the figures had grown greatly. In 1850, the United States had 9000 miles, the United Kingdom 6600, Germany 3600, France 1700, Belgium 550 and many other countries had made a fair start. Thenceforward, the iron roads advanced at an ever-accelerating pace.

We can obtain a very fair picture of the world's progress by measuring the growth of its railroads. In the table on the next page we show the advance of Europe, which now possesses over 200,000 miles of line. It will be seen from the table on page 2531 that several European nations now own larger systems than the country which invented railways. This, of course, is largely due to their areas. Germany, France and Russia are all of them far larger than Great Britain, and necessarily require more extensive railway systems. Besides the countries named, only two others in Europe — Italy and Hungary — possess over 10,000 miles of railway.

We see that in 1850 Europe could boast of only about 15,000 miles of railways. Twenty years later the length of line had quadrupled. In 1890 the figures of 1870 had been doubled. Even in the quarter century following 1890 — a date which to many of us seems but as the yesterday — some 80,000 miles of European railways were built, to which Great Britain contributed only 4000. Russia led with over 20,000 miles of new construction.

When we turn to Asia — to an area exceedingly greater than that of Europe — we get very different figures. In 1917 all Asia boasted only about 71,000 miles of line, and of these all but 34,000 were in British India, and almost the whole of the balance in Russia, Japan and China. It would have been well for Russia if she had not postponed so late the building of a steel road across Asia. Japan has multiplied her railways sevenfold in the last quarter century.

The Chinese railways have grown through the speculations of foreign concessionaires, but, despite her 7000 miles of railways, her enormous territory is for the most part just as it was before men had seriously begun to experiment with steam. The Asian record most significantly contrasts with that of Europe in the statement. Almost the whole of the Asian railways are of European origin. Such, for example, is the famous Bagdad railway, built by German interests, and thought, rightly or wrongly, to be bound up with German imperialistic ambitions in Asia. German interests lost control of this railway at the end of the Great War. In all Asia only the railways of Japan, and a few relatively unimportant lines in China, can be said to owe their building to wholly Asiatic enterprise.

As to Africa, when we remember her enormous area, we see how comparatively insignificant are the developments which have yet taken place. They are very largely confined to British South Africa and to Egypt. The Union of South Africa has over 10,000 miles of excellent railway, and Rhodesia has already over 2500 miles. Very significant is the fact that Egypt has a mileage of nearly 7500. Egypt was long nominally part of Turkey; and the fact that her railway mileage is so much greater than that of the former dominions of the Sultan is, of course, conclusive evidence of European control. Even if we did not know the historical facts, we could gage them from the railway evidence.

The vision of a through line from the "Cape to Cairo" was one of the magnificent conceptions of the great empire builder, Cecil Rhodes. The vision is now become well-nigh a reality, and the phrase "Cape to Cairo" itself has taken a lasting hold on the world's imagination. The Cape to Cairo line is notable in many respects. For one thing, it is the first transcontinental road ever built longitudinally through a continent. Other transcontinental lines, like those of the United States, run east and west from coast to coast. Moreover, it is the longest continuous trunk line ever built, its bridges are the highest and longest in Africa, new

records in speed of construction have attended its building, and it has been pushed forward under unprecedented difficulties. In crossing the Zambesi River just below the Victoria Falls, a sheer span about 500 feet in length and about 420 feet above low water, had to be thrown across a gorge with precipitous sides. This and other engineering achievements of the first magnitude emphasize again the dependence of economic progress upon science. At present, the Cape to Cairo route combines rail and water. Ultimately, very likely, through trains will go from the Cape to Cairo over a continuous line 6000 miles long. More than that, this route and its branches have opened up not only an extraordinary variety of interesting scenery, but also great mineral deposits, splendid forests of timber, and what is probably one of the greatest potential sources of water-power to be found anywhere on the earth.

We come next to America, which has more railroads than all the other four continents put together. As the head of the list, of course, the United States stands easily supreme. Her vast area of 3,600,000 square miles is now covered with a network of railroads which will soon have a mileage of three hundred thousand. It may be pointed out that it is this great call for railways by a naturally rich land which has stimulated the enormous growth of the iron and steel industry of the United States, no small part of the business of which is concerned with furnishing materials for American railroads, whether for new construction or for repair. The Canadian lines have attained a remarkable total, which has already far out-distanced that of Great Britain. Mexico, Argentina and Brazil have all more than fifteen thousand miles of railways. The growth of American railways as a whole, especially in the last twenty years, again reminds us of the stupendous possibilities of the lands which Columbus revealed to the world. In Australasia the enterprise of peoples of European origin has already constructed nearly thirty thousand miles of railways, bringing up the total for the whole world to over 700,000 miles, — not far short of twice what it was in 1890.

THE RAILWAYS OF THE CONTINENTS

(In miles)

	1850	1890	1923
Europe	14,200	139,200	225,200
Asia	—	20,900	65,200
Africa	—	5,800	30,000
North and South America	9,100	205,700	381,700
Australasia	—	11,700	31,500
The World	23,300	383,300	733,600

From one point of view this is a magnificent total, but the future, and not a very remote future, will make it seem very small indeed. It is only in Europe and in some parts of America that railway work has yet been seriously accomplished, and even in Europe and the United States there is room for exceedingly large developments.

Some facts of unusual interest are brought out by the following table:

RAILWAY MILEAGE COMPARED WITH AREA AND POPULATION

Country	Miles of Railway Per	
	100 Square Miles of Area	10,000 Inhabitants
Belgium	47.2	7.3
United Kingdom	19.3	5.2
Germany	18.7	5.9
Switzerland	18.7	8.4
Denmark	15.8	9.1
Holland	15.5	3.4
France	15.1	8.0
Italy	9.8	3.1
United States	6.9	26.7
Sweden	5.1	16.2
Spain	5.0	5.1
Japan	2.7	1.1
Malay States	2.6	11.9
Mexico	2.1	10.9
Russia in Europe	1.9	3.0
Argentina	1.9	42.2
India	1.8	1.1
Norway	1.6	8.2
Chile	1.3	11.9
Canada	0.8	41.1
Australasia	0.6	36.0
Brazil	0.5	6.5
Russia in Asia	0.1	9.6
China	0.1	0.2

In some ways, these figures are more significant than are statistics of aggregate railway mileage. For a large country, as a matter of course, may be expected to have a larger railway system than a small country. When differences in area are taken into account, however, some striking variations appear. The densely populated Belgium has five times as much railway line, in proportion to its area, as has the United States, sixty times as much as Canada, and four hundred and seventy times as much as China. Great Britain, Germany and other highly developed countries of Europe stand high on the list. But when we turn to the figures showing the miles of railway per ten thousand inhabitants, we find strikingly different results, for, as one might expect, the less densely populated countries are, in proportion to their population, better furnished with railways. Canada and Argentina stand at the head of the list in this respect, while Belgium holds a relatively low place. Australasia and the United States are also by this test well supplied with railways. China, with both a big area and a dense population, has the lowest rank by this measure, as by the other.

Our brief review of railway development, taken in its entirety, gives us a clue to an important fact. It may be summed up by saying that man, after all the centuries of recorded history, is only just beginning to feel his feet in the world, and to develop the world with the tools of science. It is but the margin of possibility that has yet been touched. When we glance from the railway figures of 1850 to those of 1870, and from thence to 1890, and then on again to the records of our own time, and when we see railways beginning to stretch across and to conquer vast areas as yet almost without populations, we can afford to cherish with confidence illimitable hopes for mankind, and not less for our own country. As 1829 is to 1929, so is 1929 to a date, not by any means removed by a time as long as a century, when the world will be producing and exchanging a bulk of commodities proportionately as great or greater than the world's output in 1929.

The economic importance of railways is so intimately bound up with national development that by far the greater part of the nations of the world have decided that they must be controlled by the responsible government of the country. Indeed, it is easier to name the countries in which railways are still privately owned than to catalogue those which have nationalized their railways. The only exponents of private ownership of railways are the United States, Great Britain and Argentina. Of the six different great French railway systems, one is now administered by the government, and the others enjoy rights which are in reality concessions, rather than rights of full ownership. By wise forethought, however, all the French railways now privately operated will revert to the state within the next generation. The government will then have to decide whether it will operate the roads itself, or whether it will again turn them over to private companies.

As long ago as 1852, Prussia took the first step in railway nationalization, but it was in 1880 that she seriously made her system national. Between 1880 and 1887 nearly all the private lines were bought out, and a vigorous policy of state construction embarked upon. Of the existing Prussian railways, more than half have been actually built by the Prussian government. In all Germany, only a few thousand miles of relatively unimportant lines are in private hands.

Germany's administration of her railroad system was closely connected with her military policy. With her enormous land frontier to defend, her state railroads were invaluable to her. They were, in some instances, so situated and so equipped with sidings that large armies could be moved in a minimum time to strategic points on the frontier. Some of the German lines, in fact, had been built primarily for strategic purposes.

This point is dwelt upon here because, although it may at first sight appear foreign to the subject of commerce, it has a very pointed relation to commerce. It is perfectly true that the interests of defense are national interests, but so also are

the interests of trade. In precisely the same way that Germany had regard for defense from a national point of view, so also she had regard for her commerce.

It is not primarily on military grounds, however, that Germany, or any other country, has subjected her railway system to public ownership. It is important to observe that in those countries where railroads are not owned by the government, they are subjected to rigorous public control of a kind unheard of in the case of ordinary industrial undertakings. In fact, no one any longer claims that railroads are in all respects like other business undertakings, or that they should be free to do as they please, or as their business interests dictate, with respect to such important matters as the rates they charge and the services they offer.

It is commonly said that the excuse for the rigorous public control exercised both by the federal government and the individual states is that railway companies are "quasi-public corporations", and as such properly subject to an unusual measure of supervision. But on examination this supposed explanation turns out to be no explanation at all. There remains the fundamental question, just why our railways are singled out as quasi-public undertakings, or as businesses "affected with a public interest". Surely railway transportation is no more vital to the nation than is the growing of grain, the milling of flour, or the baking of bread or a host of other necessary occupations.

As a matter of fact all ordinary business undertakings are subject to the control exercised by *competition*. The prices the

THE WORLD'S RAILWAYS AND THEIR LENGTH

Country	Date	Miles	Country	Date	Miles
Alaska	1923	541	Greece	1923	1,700
Argentina	1923	23,060	Hungary	1923	5,327
Australasia:			India, British	1923	38,039
Australia	1924	28,315	Irish Free State	1923	2,700
New Zealand	1923	3,180	Italy	1923	13,094
Austria	1923	4,125	Japan	1923	9,361
Belgium	1924	5,841	Formosa	1923	396
Congo, Belgian	1924	1,268	Chosen	1924	1,189
Bolivia	1923	1,170	Luxemburg	1923	330
Brazil	1923	18,594	Mexico	1923	14,214
Bulgaria	1923	1,669	Netherlands	1923	2,290
Canada	1923	40,094	Dutch East Indies	1923	4,332
Central America:			Norway	1923	2,147
Costa Rica	1923	500	Paraguay	1923	274
Guatemala	1923	485	Persia	1923	350
Honduras	1923	725	Peru	1923	2,077
Panama	1923	295	Portugal	1923	2,040
Chile	1923	5,382	Mozambique	1923	347
China	1922	7,520	Roumania	1923	7,325
Colombia	1923	1,061	Russia	1923	42,110
Cuba	1923	3,496	Serb-Croat-Slovene State	1923	5,890
Czecho-Slovakia	1923	8,500	Siam	1923	1,612
Denmark	1923	3,087	Spain	1923	9,478
Dominican Republic	1923	750	Sweden	1923	9,633
Ecuador	1923	413	Switzerland	1923	3,348
Egypt	1923	2,731	Turkey	1923	3,340
Finland	1923	2,630	Union of South Africa	1923	11,679
France	1923	25,800	United Kingdom	1923	19,570
Algeria	1923	2,500	United States	1923	262,482
Tunis			Philippine Islands	1923	791
French Indo-China	1923	1,300	Porto Rico	1923	346
French West Africa	1924	1,795	Uruguay	1923	1,633
Germany	1923	33,000	Venezuela	1923	646

farmer, the miller and the baker can charge are fixed within fairly close limits by the forces of supply and demand. The individual producer has little control over them. He has to sell at the market price, be that price profitable or unprofitable.

THE WORLD'S RAILWAY TRAFFIC

Country	Year	Passengers Carried in Year	Tons of Freight Carried in Year
Argentina	1923	58,891,405	40,620,693
Australia	1922–23	274,549,967	31,301,379
Austria	1923	301,915,375	175,067,219
Belgium	1923	207,193,257	74,218,532
Brazil	1924	48,351,056	10,778,743
Bulgaria	1924	4,184,719	2,363,467
Canada	1924	42,921,809	106,429,355
China	1922	25,475,379	20,777,886
Denmark	1922–23	2,949,544	8,093,179
Egypt	1923	27,910,000	5,018,492
France	1923	547,885,773	229,301,308
Germany	1922	*	405,500,000
Holland	1922	64,288,328	145,703,354
India	1923	459,732,400	102,100,320
Italy	1924	*	42,607,588
Japan	1923	245,234,480	54,602,406
New Zealand	1924	11,725,645	6,285,147
Norway	1924	26,550,463	6,510,876
Russia	1922	216,042,000	288,351,000
Siam	1923	2,578,066	445,954
Sweden	1924	75,694,330	61,581,099
Switzerland	1922	103,642,226	21,303,692
Union of South Africa	1922–23	51,493,889	15,804,472
United Kingdom	1924	1,591,146,000	6,565,974,264
United States	1924	951,067,086	2,331,291,297

* Figures not available.

Railways, by contrast, have a large measure of monopoly power. Most of the towns in any country have only one line of railway; many industries have convenient access to only one line; many sections of the country, and many cities, are dependent for their trade outlets on a very few railway systems.

More than that, where railroad competition would seem to be possible, as where two or more lines connect two important cities, experience has shown that it works very badly. Slight differences in rates will send nearly all of the through freight traffic over one line or another, provided that the services and facilities afforded are at all comparable. From the point of view of any one railroad, rate cutting, under such conditions, is profitable, in the sense that it is better to earn even a small income than to earn none!

A large part of the expenditures of a railroad have to be paid whether it carries much or little freight. This is true of interest on its bonds, of much of its taxes, of a considerable proportion of its office expenses, of much of its outlays for maintaining its way and structures and even its equipment. Of course over a long period of years, such fixed charges, or "overhead costs" increase as the railway's traffic increases; that is, as it improves its track, or builds additional tracks and better stations, and buys more and heavier cars and locomotives. But from the point of view of the railway traffic manager it is profitable at any one time to secure additional freight if rates can be secured that are high enough to pay the "prime costs" of moving it, that is, the *actual additional* costs created by the added freight. If this much, and just a little more, can be obtained, it will be more profitable to carry the freight than not to carry it.

The result is that even where competition between railway lines would seem to be possible, such competition sets no efficacious or practicable limit to rate cutting. It is clear that what we have called fixed charges and overhead must be paid in some manner. Some part if not all of the traffic must contribute more than the actual prime or "additional" costs of conducting transportation. But in the case of two parallel and so-called "competing" lines there is relatively little traffic which cannot be drawn from one road to the other by rate cutting. Railway history supports this analysis. Railway competition degenerates into rate wars, and leads to the inevitable bankruptcy of the competing roads. The only alternative on the part of the roads is combination. This takes on different forms: the pooling or division of competitive traffic in agreed proportions; the pooling of gross or net earnings; the leasing of one line to another; the ownership of the majority of the stock of various lines by a "holding company" organized for that purpose, etc. Whatever the form, the purpose is the same — monopoly and the unity of policy which monopoly gives.

Thus we see that in the railroad field monopoly is inevitable. In some industries, the public may think it better to tolerate a measure of monopoly than to burden itself with the trouble and expense of control. But not so with respect to railways; the economic power they wield is too enormous to be left unregulated and unchecked. Railways, by using the simple device of discriminations in rates, have the power to make or unmake the prosperity of industries, cities and of whole sections of the country. A guarantee of equal and fair treatment in respect to railway rates and service, of unimpeded access to the transportation facilities of the country, are fundamental conditions of the maintenance of wholesome competition in the nation's industry and trade. Likening the competitive struggle to a game, railways *have the power to lay down the rules of the game.* This power is too vast and too important to be permitted to be lodged anywhere except in the hands of the government. The point is not that the government always does these things well. It is rather that the power of control, whether for good or ill, cannot be lodged in any other hands than those of a government which represents all of the people and all of the interest of a state or nation. It would be as logical to permit private corporations to determine what our taxes and our tariff duties shall be as to give them the absolute power to determine what our railroad rates shall be.

We see again how intimately connected are the various branches of science. They are not in watertight compartments, in which each can be regarded as cut off from the other, to be the subject of purely separate consideration. The progress of industry and commerce, and transportation and society, are indissolubly connected; and when we affect one branch we set up changes in others. It is quite impossible to understand either existing commerce or to have an intelligent outlook upon the commerce of the future without a general grasp of scientific truth. The importance of this cannot be insisted upon too forcibly, for, if there is real danger before the American people as a race dependent on agriculture, industry and commerce, it is that they are too apt to neglect scientific attainment. We have continuously to be adapting our methods and our conceptions to the needs of our time in the light of science. It is not a matter of fighting a battle once and for all, and getting the thing done with. It is a never-ending warfare with nature which man has to wage; and the contest can only be carried on to the greatest advantage by keeping ourselves in the van of scientific progress.

The time has gone by when industrial and commercial operations were carried on in little, and slowly and blunderingly. We have arrived at an epoch in the world's history when the winning of supplies, the transportation of supplies, the exchange of supplies, the manufacture of commodities, alike call for a high standard of training and a considerable personal equipment. We have arrived at a period when, if a man is to do anything serious in the work of the world, he must have a general elementary grounding in science as a whole, and a special grounding in the branches applicable to his work.

Invention is no longer a mere seizure with a brilliant idea while shaving. That might easily be a hundred years ago, when a thousand simple ideas, such as running a vehicle on a smooth rail, or utilizing a crank motion, or blowing a piston along with steam, had not yet been "discovered" or hit upon. The scientific inventions and discoveries of today are of another order. To make a definite improvement of value in wireless telegraphy, or to discover a new element like radium, or to produce indigo blue by chemical synthesis, or to investigate the properties of the theoretical ether of space, a man must submit himself patiently to years of preliminary education and training, *merely to bring him to the point at which he can start.* It is not possible for an untrained man to do work worth doing nowadays. The captains of industry have either to arm themselves with the weapons which science offers or to suffer ignominious defeat.

Our study of trade and the road thus raises very large and serious considerations.

"VEGETABLE IVORY": FROM TREE TO TROUSERS

Photo courtesy of Pan-American Union

A female Tagua Palm, Esmeraldas, Ecuador.

The Tagua burr, large as one's head and often weighing 25 lbs.

Photo by permission of the Philadelphia Commercial Museum

The seeds, of which each section of the burr contains 4 to 6, the size of an egg, when ripe grow very hard. They are sliced and buttons turned from them.

HOW BUTTONS ARE MADE

The Mussel Fisheries and Pearl Button Industry of the Mississippi River

THE STORY OF VEGETABLE IVORY AND MUSSEL

TO the average person the button is a rather trivial object. Indeed the word has always been used in comparison as of something of little value. Yet buttons are among the most indispensable of small conveniences, and the use of them as such marks a high stage of civilization. The savage fastens his blanket or tunic, his leggings and moccasins, with strings. The flowing garments of the Greeks and Romans were also confined by strings and they wore an occasional gem to fasten the toga at the neck. Indeed, the button first appears not so much for use as for ornament.

A number of very ancient buttons were discovered by Professor Flinders Petrie in a tomb at Kopt, Upper Egypt, some years ago. The oldest of the lot, probably the oldest in the world, is of amethyst and about one inch in diameter. It is Egyptian in design, although clearly made by foreigners and represents a sacred hawk, which was the emblem of a royal soul, standing facing another hawk with the ankh, emblem of life, between them. A captive lies below the hawks. This button is credibly connected with a period 2500 B.C. Another interesting button found by the same explorer was taken from a tomb at Negadah, Egypt, with a quantity of beads of the Twelfth dynasty, which connects it with a period 2000 B.C. The button, in which there is no trace of Egyptian ideas, is of lapis lazuli; the design cut thereon appears to be an ape walking, with some inexplicable lines above the back of the ape. Below is the "thunderbolt", by far the earliest example of that famous sign known to history. Both of these buttons have piercings through the shank for the fastenings. Buttons sewed through small holes close to their edges are of a period somewhere about 2000 B.C., for in those known as Greek "island stones", made of blackened limestone, this very arrangement prevailed.

Buttons were first used in southern Europe about the thirteenth century, and were applied to dress for purposes of ornamentation only. In a manuscript poem written not later than 1300, we find the first mention of them where the hero is described as wearing buttons from his elbow to his hand. The employment of buttons increased to such an extent in the fourteenth century that their lavish use on fashionable attire was the occasion of unfavorable comment in the literature of that period. During the following century they were somewhat less in vogue. Lace and points appear to have superseded them, but they recovered their ascendency in the sixteenth century and were worn in great numbers on the dress of both sexes. They were of infinite variety as regards size, shape and material, which included gold, silver, brass and other metals, wood, horn, bone, glass, silk, cloth and velvet. In the time of Charles I, handkerchief buttons were much in style. Tastes were extravagant and we find frequent mention of buttons made of diamonds and other precious stones. Louis XIV is said to have had a positive mania for buttons, spending in a single year, that of 1685, over $600,000 for them. He bought two diamond buttons for $14,000, 75 for $120,000, and the set for a single vest cost over $100,000.

The kind of button, if consisting of a precious or semi-precious stone, a crystal or gold, worn on the hat in China indicates to which of the nine social ranks the wearer belongs. In contrast to the use of the button for purposes of adornment, we find eventually its development into the knob around which man fastened the cords or loops of strings attaching or attached to his garments. This marked an important step in button evolution, because from that time on it served a useful instead of only an ornamental purpose, and became an indispensable article of dress.

The history of button-making is in many ways a curious one. Dating no further back than the reign of Queen Elizabeth as a commercial industry of any considerable importance in England it has undergone extraordinary changes. Birmingham has always been the principal seat of manufacture there. The days of its greatest preëminence included the latter portion of the eighteenth and the early part of the nineteenth centuries, when it was the fashion to wear coats with innumerable gilt buttons. Early buttons were of cloth over a wooden disc; or of gold, steel or ivory, the last three the work of the goldsmiths who were very expert in the art of chasing and carving. Gilt buttons were first made in 1760. From that time to the present, the industry has grown rapidly, particularly in France, Germany, Great Britain, Switzerland and the United States. In the State Capitol at Hartford, Connecticut, there is a remarkable collection of buttons that gives some idea of the infinite variety that may be attained in manufacture. There we find a collection of thirty-four strings, each containing twenty-seven hundred different styles, and there are no duplicates in the entire collection.

The many varieties of buttons used on clothing may, in general, be divided into two main classes, according to the manner in which they are attached to the garment. In one class they are provided with a shank which may consist of a metal loop or of a tuft of cloth or similar material, while in the other they are pierced with holes through which the threads are passed.

The beginnings of the industry in the United States and its variety of product

Each class is made in a great variety of material and an almost infinite diversity of form. The shank buttons are usually made on the shell plan, and consist of two plates of metal with a filling of pasteboard or cloth between them, each plate having the edges turned back, and the one securely pressed into the other by machinery. The face may be covered with cloth or may be of decorated metal. The back has a hole or collet in the center through which the metal shank or cloth tuft is introduced. The principle on which all such buttons are made is due to B. Sanders, a Dane, who in 1807 moved from Copenhagen to Birmingham, and there began their manufacture. He used a metal shank and his son introduced a cloth tuft in its place. Subsequent improvements were made by other inventors, reducing the cost and increasing the rapidity of production. On this account this kind of button has had an enormous sale. In spite of the innumerable modifications that have developed, shell buttons may be classed under two heads — the decorated metallic shell buttons, which were originally gilded or silvered by early processes, subsequently superseded by electroplating; and the cloth-covered buttons, made in satin, broadcloth, velvet, silk, mohair, linen, cotton and every other description of textile fabric. The manufacture of covered buttons was not attempted in the United States until about 1825 or 1826. At that time Samuel Williston, who was the founder of that branch of the industry in this country, began covering buttons by hand at Easthampton, Mass., and by the gradual introduction of machinery laid the foundations of an extensive business. At the present time the tendency of fashion is to abandon to a considerable degree the shell button and return to the older form with two, three or four holes.

Metal buttons form a numerous class by themselves, and include those for uniforms and trousers, fancy, gilt, stamped, chased or enameled buttons, and many cheaper varieties in iron and other metals.

They are largely produced from rolled sheet brass. Circular disks called "blanks" are first punched out of the brass, or other metal, by means of a fly press which consists of a vertical iron screw with triple thread, to which is attached a horizontal arm, bending downward at the end to form a handle. A punch attached to the press rises and falls with the motion of this handle and rapidly cuts out the blanks. When large quantities of one pattern are required, an automatic machine is used, which cuts out a number of blanks at one blow. The blanks, after being annealed, are afterwards stamped, which depresses the center and forms the edge. The holes are also punched by machinery. When shanks are used they are formed of wire by a separate machine which cuts off the pieces and bends them into loops of the required form. When these are soldered on, the buttons are dressed on a lathe. They are then finished by gilding, burnishing or lacquering. Gilded buttons are sometimes finished in a dead or frosted style. Livery and other kinds having a design in strong relief are stamped by a die in a stamping press. Most trouser buttons are made either from japanned iron stamped out by a heavy die or embossing swedge, or are made as shell buttons, with the back of paper or wood, and the whole thing turned out automatically by one machine. In the latter case the buttons are afterwards japanned. Numerous kinds of composite buttons are also part metal. Brass buttons were manufactured in Philadelphia as early as 1750. The first factory in Waterbury, Conn., which became a center of the American metal-button industry was established about 1800. Hardwood buttons were made there soon afterward.

In Bohemia and elsewhere pearl buttons are often manufactured by the poorer classes as a household industry in which all members of the family can engage, the smaller children sewing the finished product on cards. In Austria, France and Germany the work has been done largely by convicts. The shells are brought from the Red Sea and the Mediterranean, and it is said that there is danger that the beds will be exhausted. It takes a shell 20 years to mature. The manufacture of pearl buttons was introduced into the United States about 1855. The raw material first came from China and entered free of duty, but in 1891 the industry received a great impetus, owing to the discovery in the Mississippi of fresh-water mollusks admirably adapted to its use. Of the 400 species of mussels found in the river, several varieties are suitable for button manufacture, and if indiscriminate methods do not imperil the supply of material, this branch of the industry, which has attained large proportions, seems destined to still further growth.

The first person to engage in the manufacturing of buttons from the shells of our native fresh-water mussels was J. F. Boepple, who for many years had been similarly engaged in Germany. Due to

Courtesy Hawkeye Pearl Button Co.

TRANSPORTING SHELL TO SHIPPING POINTS OR DESTINATION ON NAVIGABLE RIVERS

The barges carry over 100 tons each.

the abundance of suitable shells in its vicinity, Muscatine, Iowa, was selected as the site of the first factory, and it became the center of this branch of the industry, which, as other river towns from time to time established factories, has become one of the principal businesses along that part of the Mississippi between Iowa and Illinois. The most remarkable development was witnessed in 1898, when no less than 36 factories were established during the first six months. The industry gives employment at good wages to large numbers of people, supports a very important fishery at which many hundreds of persons make a living, and, most important feature of all, transforms a hitherto useless product into a valuable commodity, placed on the market at a reasonable price.

Of the many mussel shells found in the Mississippi River and its tributaries, comparatively few are utilized in button-making. The requirements are sufficient thickness of shell, a uniform color of the surface and various strata, and a degree of toughness that will withstand factory treatment without cracking or splitting. Thin-shelled mussels are of no value. Even if originally thick enough, the necessary grinding and polishing reduce them to mere wafers. The preferred color is white, but cream-colored shells are also used.

Shells with pink, purple, yellow or salmon colored nacre are not suitable, as the color fades with age and is apt to lack uniformity. Some shells that satisfactorily combine thickness and color are nevertheless valueless, because they are soft and brittle and break easily during manufacture. Dead shells that have been exposed for a long time to the action of air or water also become useless.

The species of mussel found in the Mississippi River that is principally used in button-making is popularly known as the "niggerhead". It has the general shape of a common round clam, and is characterized by a very thick and heavy shell, with a black or dark-brown outside skin and a glistening white interior, the white being uniform throughout the thickness of the shell. It is of relatively small size, the largest being only $4\frac{1}{2}$ or 5 inches in outside diameter and the average about 3 inches. It is found over immense areas, preferring muddy sand and muddy gravel bottom, but also frequently in sandy bottom. A number of abundant species, some of them resembling the niggerhead in shape, are available, but are sparingly used, on account of lack of thickness, undesirable color, and brittleness, which causes the shells to crack in cutting, and the buttons to split in facing and drilling. Several other species known along the Mississippi as "sand shells" are highly valued, and a number of kinds of "pocketbook" clams are more or less abundant and yield a good button of medium thickness. Some of the best mussels for button-making are not abundant, and the supply is irregular and uncertain. One of the best known of these is the "deer horn" or "buckhorn". It attains a large size; samples over 9 inches long have been taken from the Iowa River, and in the Mississippi it reaches a length of 6 inches or more.

Aside from the depletion of the beds by fishermen, a number of animals prey on mussels, among them the muskrat, the mink and the raccoon, the first being especially destructive. Catfish are also said to eat mussels. Physical causes are further responsible for extensive destruction of the bivalves. During freshets mud and sand are deposited on the beds and bury them. Droughts are also liable to expose the beds and cause much damage. Next to the operations of the fishermen, perhaps the most serious menace to the beds is the pollution of the water by refuse from cities and manufactures. In the early days of the industry, fishing was carried on from about August to December, and more recently it has been conducted throughout the year, even after the river is frozen. The principal fishing, however, is still done in late summer and fall, when the river is lowest. Ice-fishing is of comparatively recent origin, having been carried on first during the winter of 1896–1897. The quality of the shells is better in cold weather, when they are less brittle than warm weather, with prolonged exposure in boats, makes them.

The beds are worked with comparative ease. Little experience is required, and owing to the shoal water in which mussels are found, they may be gathered with less difficulty than is ordinarily encountered in taking shellfish.

Mussels are gathered with various kinds of apparatus, all of which are simple and inexpensive. The contrivances which have been in use are the hand rake, the tongs, the rake hauled by a windlass, the dredge operated by steam and the bar with hooks. Though essentially alike, the rakes are of several patterns. The commonest form, known as the "shoulder" rake, has a wooden handle from 14 to 20 feet long attached to one side of an elliptical metal frame; on the under side of the frame are 12 to 14 iron teeth 5 inches long; the head of the rake is converted into a kind of basket by a piece of coarse wire netting attached to a frame. The rake is used from an anchored boat, the handle being placed over the fisherman's shoulder, and the rake placed up stream to the full length of the pole. The fisherman then slowly works the rake toward his boat, lifts it perpendicularly from the water and empties the mussels into the boat. This rake is also used through the ice. The tongs, known also as "scissors" rakes, are similar to the ordinary oyster and clam tongs. The dredge or rake used with a windlass is larger and heavier than the shoulder rake and of different shape. The bar with hooks, locally known as the "crowfoot" rake, is an ingenious contrivance depending for its action on the habits of the mussels themselves, and is now the leading means for taking them. It consists essentially of an iron rod 6 feet long to which are attached at intervals of about 6 inches a series of chains, each carrying a number of four-pronged wire hooks. The mussels rest on the bottom, or partly buried in the mud or sand, with their shells turned up stream and separated to admit the water, laden with oxygen and food. When touched they quickly close them, and if a foreign body is interposed between them it is tightly held. The fisherman throws the crowfoot rake overboard and allows his boat to drift downstream. As the prongs come in contact with the shells they close on them with so firm a hold that, when the dredge is drawn in, considerable force is required to detach the mussels. For anyone who has not seen the apparatus in use it is difficult to realize how effective it is. Often where mussels are abundant almost every prong will have one and sometimes two or three on it.

Courtesy Hawkeye Pearl Button Co.

FIVE THOUSAND TONS OF CUT SHELL

The fishermen have tanks, made of sheet iron, located at some convenient place on shore in which the catch is boiled 10 to 15 minutes, when the mussel falls or is readily picked out by hand. The shells are loaded in sacks and sent by steamer or taken to market in the fisherman's boat or heaped on scows and towed to the factory, or sold on the shore to buyers.

The Iowa and Illinois button factories located on the Mississippi obtain their supply of shells from grounds which extend a distance of some 200 miles, from Fort Madison to Sabula, Iowa. This part of the river is quite shallow, a necessary requirement for mussel growth and fishing. The natural tendency of some of the species is to form in more or less dense beds, while others are uniformly distributed. On some grounds practically all of the mussels are of one species, while on others several species may be mixed in varying proportions. The largest and most compact beds are formed of the niggerheads and muckets. On new grounds the niggerheads are sometimes so thickly disposed that practically the entire bottom over a large area is covered and the shells are often found several layers deep. In holes or depressions in the sandy or muddy bottom they are often discovered in thick piles, and many bushels may be taken from one of these holes.

The mussel shells as purchased from the fishermen are hauled in drays or wagons from the boats to the factories, where they are stored in covered sheds, the different kinds usually being kept in separate bins. Preparatory to being used, the shells are sorted into sizes by boys. Usually three sizes of niggerheads are recognized. Another preliminary step is the soaking of the sorted shells in barrels of fresh water for three to six days to render them easy to work. Even when only a few hours out of the river the shells become dry and brittle. It is necessary that they be used while wet, otherwise they crumble and split in manufacture. The next step is the cutting or sawing of the rough blanks. Each cutter has a pile of selected shells at hand, and, in the large factories, he is kept supplied by boys. Niggerhead shells are usually held with special pliers while being cut; these grasp the circumference of the shell and retain it fast while holding the shell at right angles to the saw. Some operators have the hand gloved or mittened, and use no pliers or pincers. At the larger plants a fine jet of water plays on the shell, as the saw revolves, in order to prevent the formation of dust and to keep it cool.

The fine dust is very irritating to the respiratory passages and eyes of the cutters, and at some of the factories is drawn into a tube by a current of air. The cutters in the smaller works often cover the mouth and nose with a cloth or sponge. The saws are made of flat steel strips, provided with fine teeth on one of the edges. These are accurately bent into cylindrical form and fitted into heavy iron holders; the latter are adjusted to a lathe in which they revolve on a horizontal axis. As the blanks are cut they pass back into the saw and holder and drop into a box provided for the purpose. From the cutting machine the blanks are taken to a weigher and recorder. By far the largest number of factories produce only rough blanks, which are sold to a local finishing plant or sent to large concerns in the east, some of which have established their own saw works on the Mississippi. The next step in the making of a complete button is the dressing or grinding of the back of the blank, to remove the skin and make an even surface. To accomplish this each blank has to be held with the finger against a revolving emery wheel. This is followed by turning or facing, which gives the front of the button its form, including the central depression. The next step is the drilling of 2 or 4 holes for the thread. The button is now complete, with the exception of the polishing process; this brings out the natural luster which has been lost in grinding, and which gives to these buttons their chief value. They are placed in mass in large wooden kegs, known as tumblers, in which they are subjected to the action of a chemical fluid at the same time that the tumblers are revolving on a horizontal shaft. By mutual contact combined with the effect of the fluid, the buttons become highly polished while the fluid is churned into a milky froth. After being washed and dried the buttons go to rooms where they are sorted into sizes and grades of quality, and then sewed on cards and packed in pasteboard boxes.

At Muscatine there is a small business done in treating buttons chemically to make them resemble "smoked pearl".

Courtesy Hawkeye Pearl Button Co.

THE PEARL BUTTON INDUSTRY — SORTING AND GRADING

The unit of measure of size of the buttons is the line, which is one-fortieth of an inch. The buttons manufactured on the Mississippi are from 12 to 45 lines in diameter. The largest, 40 to 45 lines in diameter, are made from niggerheads. A medium-sized niggerhead produces four or five 18 or 20-line blanks, while from the large shells eight or ten blanks may be cut. Sand shells average twelve 20-line buttons. The largest deerhorns produce as high as twenty-five or thirty 20-line blanks. In sawing the blanks a large part of the shell cannot be used, as it is incapable of being made into merchantable buttons. The relatively thin margin of the valves and the thick beak or umbo furnish the principal waste.

Courtesy Hawkeye Pearl Button Co.

CARDING AND PACKING

The amount of the unserviceable raw material is extraordinarily large, though it varies with the different species and factories. It is estimated that in the aggregate it probably represents over 75 per cent of the weight of shells handled. In facing, grinding, drilling, and polishing the blanks, and in defective blanks, there is a further waste. With the principal mussel employed, the niggerhead, more than 90 per cent of the material, by weight, is finally discarded. If a market could be found for this enormous waste it would prove a boon to the industry. Though it is felt that it undoubtedly has a value, it has not yet been much used except to a very limited extent in road making. It is said to make a valuable fertilizer, but so far no great demand has been created.

The danger of exhausting the mussel supply

Although mussel fishing along the Mississippi River is comparatively new, there has been a more or less marked reduction in the abundance of mussels of all kinds utilized in making buttons, and in some localities the depletion of the beds has been almost complete. As the time required for a niggerhead mussel under normal conditions to reach a marketable size is 10 to 20 years, the serious effects of indiscriminate fishing are evident, and great solicitude has been felt by the button-makers and others lest their raw material should be exhausted. This has been the subject of recent investigation by the United States Fish Commission, and measures have been advocated through which it is thought the supply will be indefinitely maintained.

Some difficulty was at first experienced in putting on the market buttons made from our native fresh-water shells, but the demand rapidly developed, as their quality and price became known, and at present Mississippi River buttons are sold in every state in the Union and even in foreign countries, and constitute one-third of the total output in the United States. At present about 50,000 tons of clams are consumed in a production of over 25,000,000 gross of pearl buttons per annum.

How the nut of a palm tree is utilized in button making

Vegetable ivory has long been a favorite material for the manufacture of buttons because it can be readily sawed, carved and turned in lathes into all sizes and shapes, while the texture of the material is such that it readily absorbs dyes and also takes on a high and permanent polish. To look at a nicely made button that so artistically harmonizes with the fancy grays, browns or blues of men's attire, the casual observer would hardly imagine that it is a purely vegetable product, in fact, the seed of a tree. It has been little more than fifty years since some rubber gatherers in the forests of northern Ecuador first told of a peculiar species of palm which they found in great numbers, whose fruit resembled in form and color the miniature head of a negro. These nuts they therefore called "negritos", and it was found that the kernels, when thoroughly dried, had the appearance and texture of dentine ivory. Sample lots were sent to Europe for experimental purposes, and although they were at first thought to be useless, it was found upon further investigation that they furnished an ideal material from which to manufacture buttons and other small ornamental objects, for which the more expensive ivory had hitherto been used. This seed or nut is now known almost everywhere as the vegetable ivory nut. In its native land it is called the Tagua, or Coroza nut. The photograph shows the fruit of one of these, *Phytelephas macrocarpa*, *Palmæ*.

The tagua palm is found near the west coast of South America, from southern Panama, through Colombia, Ecuador and northern Peru. It is most plentiful along the eastern slopes of the Andes and flourishes in groves along the river valleys at varying elevations above sea level. The tree is, in reality, a stunted palm fern and grows very slowly to a height of 10 to 20 feet. On the whole it presents a fine appearance. The leaves, bearing a very close resemblance to those of the cocoanut palm, are thrown out around the central stem, which after growing and shedding the

Courtesy M. B. Shantz, Inc.

IVORY NUTS FROM WHICH THE OUTER HUSK HAS BEEN REMOVED

leaves for 5 or 6 years, forms the trunk, at that age not over 3 or 4 feet high, crowned by a canopy of leaves resembling large green feathers. At this time fragrant blossoms appear at the bases of the lowest leaves to be fructified by the pollen borne to them by the winds or carried by the myriad insects from the nearby male tree. Each fruit is composed of a dozen or more separable fruits, one of which, broken open, is shown at the right side of the picture. In each section of the large fruit, there are four to six seeds the size of an egg. These are embedded in pulp and many coverings and are first in the form of sacks of sweet, refreshing liquid that changes into a soft, delicious pulp, and finally becomes the hard nut of commerce.

The nuts mature very slowly, requiring fully a year from blossom to full ripeness. A collection of 60 to 90 nuts in groups of 5 or 6 are incased in one huge, knobby husk resembling a chestnut burr but much larger. (See frontispiece of this chapter.) This head opens at the bottom when the nuts are ripe and lets them fall to the ground. They are covered with a thin, oily substance which attracts the wild hog, guanta, guatusa, squirrel and other rodents that leave the nuts clean for the gatherer.

Courtesy M. B. Shantz, Inc.

SECTIONS OF IVORY NUTS

Care in sawing must be taken to avoid the cracks that occur in drying.

There still remains a creamy white dry substance which rubs off in handling and leaves the hard black shell resembling the skin of the negro in color and texture. The nuts are about the size of small potatoes, of very hard, white composition; fine-grained, and closely resembling dentine ivory. The finest nuts come from Ecuador and Colombia. Here, in or near the fertile river valleys the tagua palm flourishes in groves, scarcely any other vegetation being mingled with it. As the tree grows wild and uncultivated, the time of bearing and the length of life of the tagua palm has not been definitely ascertained, but it is claimed that they begin bearing in their sixth year and that they live from fifty to one hundred years.

The largest tagua forests are from three to six days canoe journey from Esmeraldas and Guayaquil, the chief ports of Ecuador. The native gatherers, known as *taguaros*, work in pairs or small parties, and subsist largely on wild game. Having established camp, as near as possible to the forests, baskets are woven which will hold about 200 pounds of nuts and rafts built on which to transport them down stream to the markets. If the trees are distant from camp mules are used, but usually the natives carry the baskets on their backs, a very exhausting task attended with danger from snake bites and disease brought on by constant exposure. When ten or fifteen tons of nuts have been secured, the filled baskets are placed in rows around the outer sides of the deck of the raft or boat, leaving an open space in the center for loose nuts, and the craft is headed down the river to one of the trading stations, where they are sacked and shipped to the button factories of the world.

The ivory nuts as they are received at the factory look very much like small potatoes. They are still incased in exceedingly hard flint-like shells which are capable of resisting the hardest steel, yet can be cracked open with a sharp blow. To remove the kernel they are spread out and dried in a temperature of about 100° F. until the shells become loose and easily separable.

They are then placed in tumbling barrels or drums, and are thus mechanically separated from the shells. After several hours of tumbling the nuts are individually inspected and the minutest particles of shell which may still adhere are removed. Next they are taken in an automatic carrier to the sizing drums where they are automatically sized and bagged. Thence they go immediately to the saw room where the pieces of button slabs are cut from around the core of the nut by high-speed circular saws. The core is usually more or less hollow and pithy and has to be discarded. The pieces, or green slabs, are now subjected to a high temperature in dry kilns where they undergo a period of curing for about six days to remove every bit of moisture. Each piece is now as hard and dry as a bone, and, regardless of how it may be swollen or soaked in subsequent process of manufacture, it always returns to its present state of hardness. After the pieces are sorted by revolving drums they are ready for the turning room. But before being put on the lathes, the slabs are immersed in a steaming hot bath to moisten the outer surface and prevent cracking. In the turning room the ivory is rapidly cut into the required size and shape of the "blanks".

The most accurate and complicated machines in the factory are those which drill the holes. It is also their function to ream the edges of the holes, so they will not cut the thread, and if it is a niched button, to cut the little grooves on the faces between the holes. This is all done in one operation; the blanks from the turning room being poured in at the top, the machine automatically faces each button in the proper direction, and holds it in place while the holes are drilled and reamed. As soon as the button blanks have been drilled they are taken to the drum room and rolled in large tumbling barrels with polishing material which gives them an extremely smooth surface. The next process to which the white ivory is subjected is that of coloring, giving it the shade and design to match or harmonize with the woolen for which it is intended, perhaps not yet on the market.

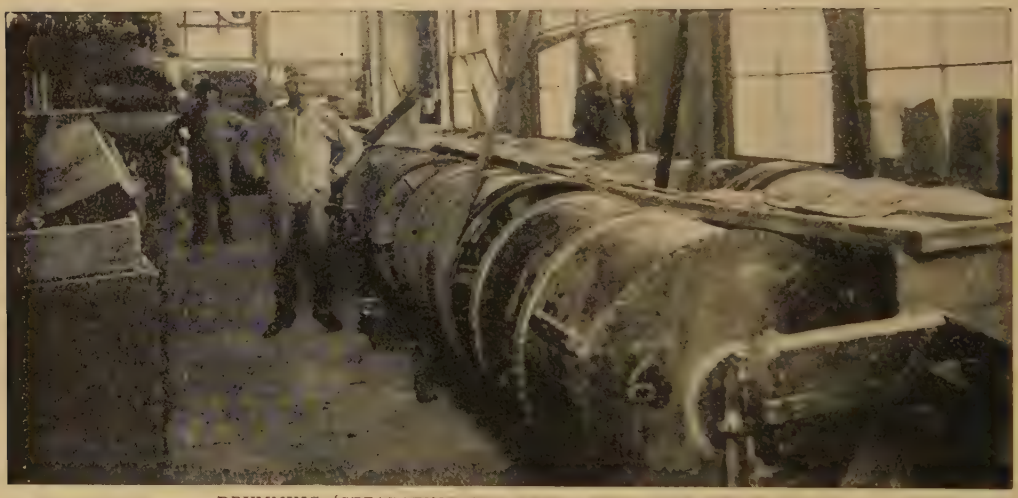
INITIAL STAGES OF MANUFACTURE

Courtesy M. B. Shantz Inc. and Art in Buttons Co.

SAWING IVORY BUTTONS (*above*) AND TURNING THEM INTO CIRCULAR FORM

HOW THEY MAKE OUR IVORY BUTTONS IN SOME

POLISHING AND FINISHING



DRUMMING (SEPARATING THE SHELL FROM THE KERNEL)

Courtesy M. B. Shantz Co.

PRESSING AND EMBOSSING

OF THE GREAT ROCHESTER BUTTON FACTORIES

DRILLING THE HOLES IN THE BLANKS

COLORING IVORY BUTTONS

Courtesy M. B. Shantz Co. and Art in Buttons Co.

SORTING AND INSPECTING THE FINISHED PRODUCT

Buttons may be either in solid or mottled colors. The dyeing of the first class is a fairly simple process, that of the latter is more complicated. First they are soaked in water to open the pores and further prepare the surface for the reception of the coloring matter. Then they are placed face up on a pin board containing a gross of buttons, which, in turn, is passed to a dyer, who places a chart or stencil over the pin board, and with the aid of an air brush sprays the buttons with a "resist" dye. The chart is then removed and the board passed to a second dyer who, with the aid of a similar chart, sprays the buttons with the "color" dye, and sets it out to dry. When the buttons are thoroughly dry they are taken from the pin board and placed in a vat of color bath or developer, which brings out the spray color and renders it fast, and also gives a medium shade to that part of the button which has not been sprayed at all. The color being firmly fixed, the "resist" is removed and there is left a finished button, though rather dull in luster. To bring out the color and finish, they are again drummed for several hours until they acquire a high polish. There is no limit to the variety and beauty of coloring which can be produced in this way. Great variety may also be obtained by the kind of finish, and the button may be either polished, dulled or pressed, or a combination of any of these. Finally the buttons are taken to the carding room, where they are individually inspected, sorted, shaded and sewed on cards. Before being placed in boxes they are again inspected on the cards to see that all those on one card are exactly the same, and then packed ready for shipment.

Probably few people realize the importance of this branch of the button business and the extent to which the industry has grown in the last few years. The United States buys annually more than 10,000 tons of tagua nuts, for which is paid upwards of $1,500,000. There are 23 vegetable ivory factories in this country, representing an investment of $4,000,000, and giving employment directly and indirectly to more then 10,000 people.

This constitutes fully one-third of the button business of the entire country. The leading center of manufacture is Rochester, New York, which has the three largest plants, and makes, it is said, the highest grade of goods in the world. In following the process of manufacturing buttons from ivory nuts the tremendous waste involved is again to be noted. Through shrinkage, sawing and defects, more than half of the original shipment is lost and the manufacturer pays for the handling and transportation of an enormous amount of unused material. In the reduction of the product from nut to slabs the element of skill is almost negligible, and this, it is thought, could be easily accomplished in the country where the tagua palm grows. Steps have already been taken in this direction.

It has been said by a leading manufacturer in the Birmingham district that it is easier to write out a long list of material from which buttons have been made than to name one from which they have *not* been made. Among the animal substances used are ivory, bone, horn and hoof. Buttons made of hoof under the name of "horn buttons" were introduced about the middle of the nineteenth century by E. Bosset of Paris. These had a great success in their day and were made in enormous numbers by pressing them in heated dies in which the design was cut. They were manufactured extensively for a good many years at Birmingham, and sent to all parts of the world. Horn buttons were made in the United States as early as 1812. They were very popular for years, but have given way to ivory, bone and vegetable ivory, mother-of-pearl and celluloid. Mother-of-pearl buttons are formed of the beautiful substance of which the large flat shell of the pearl oyster consists. Small cylinders are cut out of the shells with a tubular saw, split into disks, drilled with holes, and polished with rotten stone and soft soap, or with ground charcoal and turpentine. Shirt studs as well as flat and globular buttons with metal shanks are also made of mother-of-pearl, which may be either of the ordinary color or smoked. Pearl shirt

buttons are made in great quantities both in the United States and in Europe, and often of a cheap substitute. Porcelain buttons were a few years ago nearly all of French manufacture, but they are now made principally in Prague. The plastic clay is pressed into molds of plaster of Paris in the same way that small objects are usually produced in earthenware. Celluloid buttons are made in mold like the vulcanite and horn.

More or less expensive buttons are made of ornamental stone, such as agate, jasper and marble. Occasionally, they are formed of amber, jade, or of still more costly materials, as pearls and gems. Glass buttons are made in great variety. For "punched" buttons small rods of colored glass are heated at the ends, and pressed into shape by means of a pair of rather long hand pliers, on the ends of which are a die and its counterpart, likewise kept hot. Other kinds are cut out of colored sheet-glass, which is coated on the back with tin amalgam like a mirror. Along with these varieties some beautiful glass buttons are made in Bohemia, either partly or wholly of aventurine glass; and of this gold-spangled material, artistically inwrought with other colors, studs and solitaires still more remarkable for their beauty and minute patterns are made in Venice.

Fancy or ornamental buttons for women's dresses are sometimes made of combinations of cloth and glass or papier-mâché pearl, metal or choice woods, sometimes of vulcanite or glass, but oftener at the present time of silk, velvet, silk cords and figures, or what is known as passementerie, or of brocade and embroidered silk. These are usually made upon a wood foundation, especially if they are oval or fanciful in shape. Their manufacture is often carried on in connection with other dress trimmings. Different kinds of wood, such as beech, boxwood, rosewood, lignum-vitæ, zebra-wood and walnut are manufactured into buttons. Wood molds or cores for women's buttons, which are covered with cloth of the same pattern as a dress, are made in enormous numbers in the south of France.

Various kinds of composition buttons have been made since the industry was started in this country some fifty years ago. The first of these, a button resembling vegetable ivory, was produced from certain fossil and vegetable gums combined with finely comminuted carbonate of lime, feldspar or mica. Composition buttons are now made of many materials, among them the Irish potato, which, when combined with certain acids, becomes as hard as stone. Other materials are the casein from skim milk, blood and brown seaweed. A unique branch of the industry is the manufacture of campaign and society buttons, and of buttons on which photographs are reproduced or ornamental designs for purposes of advertising or ornament. These are usually made from celluloid.

In recent years the old hand methods of making buttons have been superseded by machinery. Numerous ingenious devices have been invented whereby many kinds of buttons are made wholly or in part by automatic devices and turned out with marvelous rapidity. Up to the year 1900, 348 patents for button machines and 1355 for the making of buttons had been issued by the United States Patent Office.

In England the city of Birmingham is still the seat and center of the button trade, which, however, is much more largely developed in France and Germany. Machinery has recently been introduced into the button-making factories of Japan, and with the abundant supply of shells found on the neighboring islands and imported from India and the Dutch East Indies the industry has grown enormously. Great quantities of pearl buttons are yearly exported to Great Britain, France and Germany, and the trade is rapidly increasing. Notwithstanding this newly developed branch of the industry and the growth in other countries, notably Germany, census reports show that our exports of buttons are steadily increasing, while our imports, formerly great, have decreased to an extent that reveals what an important place among our leading industries the button business has assumed.

DAWN OF THE SCIENTIFIC CURIOSITY WHICH HAS RESULTED IN MODERN INVENTION

DR. WILLIAM GILBERT, PRESIDENT OF THE COLLEGE OF PHYSICIANS, SHOWING HIS EXPERIMENTS IN ELECTRICITY TO QUEEN ELIZABETH

SOCIETY AND INVENTORS

The Danger of a Socialism Which Would Kill the Spirit of All Originality and Progress

WHAT A PEOPLE WINS BY LIBERTY

WHAT is the prize that a people wins when it has slowly and painfully transformed its old coercive forms of government into a new system of free institutions? Is it happiness? Is it wealth? Is it power?

Well, the Anglo-Saxon nations are distinguished for the spirit of liberty that pervades all their social life. We have possessed for some centuries a form of government freer than that of any other civilized race. Nearly all the modern machinery of political liberty has been conserved and developed by our forefathers and ourselves and our kinsmen far scattered over the seas. Even the French Revolution, which shattered the feudal structure of continental Europe, was only a partial manifestation of the new spirit of liberty created in the conscience of the Anglo-Celtic race. Here and there, perhaps, another people has bettered the ideas she learned from the Anglo-Saxon, but on the whole our race is still leading the way in the evolution of free institutions.

Yet it is very doubtful if we are as happy as the more backward races of the world, with their simple needs, their quiet life of routine and their pleasant and leisurely ways of existence. Exempt from the fever of the soul and the turmoil of the spirit, that trouble and weaken many of the best minds of all our classes, they form reservoirs of mental and physical force from which human society will draw a new supply of strength when we perhaps fail and fall under the burden of progress. Already it seems likely that some of the backward races of Europe, now streaming into the United States, will in a few generations be carrying on the civilization founded by British settlers. Careful studies of birth-rates in Massachusetts by Kuczinski and in New Hampshire by Dr. Allyn A. Young have shown not merely that the families of the foreign-born are several times as large as those of the old American stock but that the American-born do not have children enough to maintain their numbers and are actually dying out. A very recent analysis of New York figures by Dr. Royal Copeland shows that the birth-rate for foreign-born is thirty-eight per thousand; for the native-born, sixteen per thousand; and for typical American neighborhoods, seven per thousand. Not only this, but the death-rate for infants in the first year of life is fifty per cent higher among the American babies than among typical foreign nationalities.

Whether this means a displacement of "better" by "worse" is a question which will be answered readily — on the basis of race pride. But all will agree that it is a deplorable thing that the element of our population which is most truly American does not find life worth perpetuating. Surely it is not happiness that the Anglo-Celtic race has won by its long and victorious struggle for liberty. And can it be said that our people generally have gained the prize of great wealth? It is a notorious fact that before the Great War a full third of the population of England was suffering from extreme poverty and conditions in the United States were only moderately better. These people at least have won very little happiness or riches by the development of free institutions in which they take so much pride.

The English serf of the Middle Ages was often more fortunate in the conditions of his life than is many a free laborer in modern Europe or America. He had land from which to win his food, pleasant and healthful surroundings and many opportunities for rural sports and pastimes. Enormous as is the wealth of the modern nations, it can scarcely be maintained that the actual proportion of the means of living among the various classes of our population has been increased in a way favorable to general well-being.

So, if we are candid, we shall be inclined to admit that after some centuries of freer government than any other large nation, ancient or modern, ever enjoyed, we have not generally become happier and richer than our ancestors were. "Merrie England" has disappeared, and America never was merry; the lively sense of the joy of life is gone. The spirit of modern life is that of hard calculation in the economic sphere and puritanical severity in the social, relieved by the mechanical and artificial gayety of the night life in our cities and underlain everywhere by the slumbering embers of revolt. We have become more somber-minded than our ancestors, more hard-working, perhaps, and certainly more ambitious for material success, but we have forgotten the art of taking life easily, pleasantly and naturally. But it will be said that our nation is immensely more powerful than was any nation under feudal or monarchical rule. It is true that the British people have increased and spread from a nation of some five million in the middle of the seventeenth century to a group of nations, colonies and dependencies of five or six hundred millions, while the wealth and material resources have increased in vastly greater ratio. Yet it cannot be said that their military power has increased in any such proportion. That spirit which fosters democratic government is inimical to warfare for two reasons. In the first place the moral spirit of democracy is opposed to aggression and conquest and prefers discussion to violence as a method for settling disagreements among nations as among individuals and groups.

And in the second place, the prime condition of success in modern war, conducted by machinery and on a national scale, is the effacement of the individual, subordination to discipline, unthinking and unquestioning obedience to the orders of superiors in carrying out plans of the nature of which the fewest possible number of men have any knowledge.

What is quite clear and pertinent here is that, in time of war, democracy has to be submerged in the interest of a more unified system of control. The Roman republic temporarily established absolute monarchy in times of national crisis in the person of a dictator whose power was supreme over all civil officials. The wars engendered by the French Revolution caused the transfer of power from the Assembly to a Committee of Public Safety and finally the transformation of the republic into the Napoleonic consulate and empire. The action of the people is too much concerned with the ultimate implications and consequences of each decision, and consequently tends to slowness of movement and even to cross purposes.

That the decisions and acts of democracy are likely to be the right ones ultimately, we in America like to believe, or we should not have poured out our blood and treasure in a foreign war, with the immediate issues of which we were not concerned, because the safety of the world for free institutions seemed to be at stake. And that democracy does triumph in the long run is the clear verdict of history. But immediately a militaristic state, such as Germany was in 1914, can accomplish vastly more with the same human and physical resources than can the more popularly governed nation. This was clearly shown by the course of the war in its first years. And America, untutored in habits of obedience to authority, would have made a far poorer showing than did France and England if the war had come to us as it came to them.

But in the long run of affairs, democracy does triumph, clearly has triumphed, and proves more satisfactory to the people than subservience to any established despotism or aristocracy.

Inventiveness the great advantage derived from the spirit of liberty

It is clear that free institutions are not to be justified on the ground of increasing a nation's military power, nor, likewise, on the ground of promoting happiness. They are a source of weakness rather than of strength. What, then, is the prize that the Anglo-Saxon peoples have gained by being the first to work out a form of government applicable to a large nation animated by the spirit of liberty, and which has made the world so ready to follow in the way that they have marked out? In our view the supreme quality of a law-abiding, alert and free people is inventiveness. Of course, there are many other things that go with liberty, but they are direct attributes of a state of freedom rather than a new and extraordinary social power produced by the effects of free institutions on the popular mind. A genius for invention, however, is a kind of prize that a people wins when it combines the habit of coöperation with the marvelous power of personal initiative which finds a universal scope only under free and equal government. And the fruit of inventiveness is progress. The unprecedented advancement in all fields of civilization which marks the past two centuries is unquestionably connected with the growth of free institutions which has taken place in the same period. It has been pointed out, especially by Dr. Thorstein Veblen in the case of Germany and England, that the brilliant achievements of the more centralized state are based on the exploitation of ideas and tendencies originated by the freer one but applied more rigorously and efficiently by the better drilled and regimented people.

Many writers have contrasted the beneficent power of a single enlightened and able ruler with the slow headway made in certain social reforms, after they have been recognized as necessary, by a free people. A large body of men who settle things by discussion instead of by coercive commands is bound to be slower, very often, in its movements than a despot endowed with genius.

Despotism — power without inspiration or originality

And it must be admitted that, in matters requiring instant decision and swiftness of execution, a centralized government will possess a great advantage over a nation that does not act under orders.

This is the case not only in war, but in many important social reforms. A man who wields an absolute state control can effect in a few years new movements of high importance, which a generation of free people could not carry out to completion. The condition of England and the United States in contrast with that of Germany at the outbreak of the Great War is proof of this. Germany took the lead by a generation in the matter of social responsibility for the health and comfort of the masses of the people, and even in the field of education showed a far lower percentage of illiteracy. Modern democratic society has so many gross and flagrant defects that the woeful spectacle of them has made many men besides Thomas Carlyle long for the swift and trenchant rule of a reforming despot. But a despot, after all, is only a single man; and it is very infrequently that he combines a genius for reform with a natural passion for power A despot seldom originates. He is power without inspiration. He is often a good organizer, and if he is served by ministers with a large experience of the needs of the people, he may distinguish himself in domestic affairs as well as in wars of conquest.

Modern industry the fruit of invention due to individual initiative

It is often said that the growth of industrialism is the force behind the modern movement of freedom. But we are inclined to put it the other way. When the Roman Empire was rotting into a despotism, the industries and commerce of the people were much superior to those of the English nation in the days of its early struggle for free institutions. If industrialism pure and simple has done such good work in the modern world, why were few or none of its effects on political institutions visible in all the

great despotic civilizations of the ancient world? Our view is that modern industry is the fruit of invention of a very high order; and this extraordinary inventiveness is directly due to the development of individual initiative and individual versatility of mind, elicited by a new spirit of liberty that is partly religious in origin. Indeed, we will go farther, and say that the modern industrial revolution has a different beginning and a different direction from that of the industrial movements in ancient civilizations. It arose through no national necessity. The fact is that the best minds could not help inventing, any more than they could help thinking.

The remarkable achievement of free enterprise in the transformation of industry

The whole character of the social and economic life of the people in modern nations is to an almost incredible degree the product of changes which have taken place within less than two centuries, and which first gained headway in England. The freeing of the human spirit from the thraldom of medieval ignorance and religious and political despotism resulted in many humanitarian movements, and especially in an agitation for the abolition of human slavery. It is questionable, however, whether this agitation could have succeeded if the genius of the freest of the great nations then existing had not proceeded to invent and build wonderful iron slaves that could do much of the hard, brutalizing work, the necessity for which had always kept a large part of the human race in mental and physical subjection. At first the new machines were driven by the force of running water, but very quickly another inventor, James Watt, gave to the world the new power of steam, which now saves so much muscle and makes possible so many feats which muscle not thus aided could never have achieved. All that machinery and mechanical power mean to modern life goes back in a real sense to the English industrial revolution of the eighteenth century, and a large part of it to inventions made by Englishmen and Americans in the short space, historically speaking, of little more than a century.

At the same time that industrial processes and economic life were being transformed, the increased productivity of English industry under the new methods enabled the nation to carry to a successful conclusion the great Napoleonic wars, and to save western Europe from the menace of a military despotism. The transition period, to be sure, was one of much suffering in England, but it is wrong to ascribe this entirely to the new inventions or the growth of "capitalism," as some writers have been inclined to do. The wars of the time cost more than the total wealth of the country had been when they broke out, and at the same time there was an unprecedented series of crop failures, while the foreign trade on which England was already largely dependent for food was seriously crippled.

How a continent was conquered from the wilderness by individual initiative

While the most democratic of the Old World nations was revolutionizing industry and transforming the character of human life, a group of its colonies threw off their allegiance, set up for themselves on a still more democratic system, and undertook to win a wilderness for civilization. Inspired by the most intense individualism the world has seen, the people of America have gone resistlessly forward, pushing the frontier farther and farther west and transforming frontier life into ordered society a few hundred miles in its rear, until today our flag floats over an area practically the size of the whole continent of Europe. And throughout this great domain the people live on a plane of civilization, comfort and refinement which is now far in advance of that of much of the Old World, from which our civilization was originally drawn. Much indeed has been crudely and even blunderingly done, but on the whole the result, and the expedition with which it has been accomplished, are out of all comparison with anything the most ideal bureaucracy could have achieved. Free enterprise makes mistakes, and often works at cross purposes, but in the end it finds a way, and performs wonders which an organized despotism would declare to be beyond the powers of man.

Excesses of individualism; the need and dangers of organized political control

It would not be true to say that there were not serious evils connected with these magnificent achievements of free enterprise. In the industrial revolution there was much unsettlement, and dreadful abuses occurred. Hundreds of thousands of skilled craftsmen were deprived of their former means of livelihood so suddenly that much suffering ensued before a readjustment could be effected. Moreover, the suffering was greater than would have been necessary had there been more centralized control during the transition period. Individualism has a way of taking short cuts to its goal and not looking much to consequences very far from its immediate path. In this respect it resembles despotism rather than democratic social action, and is perhaps even narrower in its outlook than the former. The human resources of England were exploited in a ruthless way in the early part of the modern period. The abuse of women and children in industry before the passage of the Factory Acts is notorious. In the coal mines, women clad in rags were employed to draw the cars of coal up long inclines to the surface. The passages were so low that they were compelled to crawl on their hands and knees. Lads of tender years sat for twelve hours in utter darkness opening and closing doors between the various compartments in the galleries. Overseers of workhouses farmed out pauper children of seven years to manufacturers who literally worked and flogged them to death. Sometimes they agreed to take one idiot for each nineteen sane children. Mortality was especially high among apprentice chimney-sweeps, who were starved so that their bodies would pass into the chimneys, and were often suffocated by the soot.

In America, also, the conquest of the wilderness has been carried out in a manner which, though amazingly effective, has often been wasteful. It is noteworthy that the early development of factory industries in this country took place under rather idyllic conditions, due to the competition of high wages for agricultural labor and of the opportunities for pioneering. By the time when serious abuses became possible, the example of other countries led to a comparatively rapid development of welfare legislation. The conspicuous waste in America has been that of natural resources rather than human abuses, and in this field it has indeed been almost appalling. Lands have been stripped of their forest cover without consideration as to the effect on the flow of streams, and as a result our river valleys have been subjected to floods greater than were known before, the soil washed away from extensive areas, and the value of the streams for power or navigation destroyed because in the dry seasons the streams shrink away. Our national resources have been developed from the standpoint of immediate private profit rather than that of ultimate social utility. Forests have been wastefully cut, minerals wastefully mined, many railroads built unwisely for competitive or even blackmailing purposes, and many things done which it will cost much to undo, to restore conditions that might have been kept from the start at relatively little sacrifice. The æsthetic side of life in particular has been shamefully disregarded. Where the preservation of natural scenery conflicted with immediate economic gain, the latter triumphed and our cities have been located, laid out and built with a shocking indifference to beauty, and often to ultimate convenience.

What apology can be made for wanton waste of our economic resources

Of course something is to be said in apology for the apparent wantonness in the disposition of our economic resources, and the jarring disregard for wholesomeness and beauty in building cities in our early history. The economic problem at any one time always involves delicate decisions as to what things to make and use, and how much of each, and no phase of this question perhaps is as hard to adjudge satisfactorily as that of the relative weight to be given to future as against present wants and needs. It is at this point that an individualistic competitive system is

weakest. It is likely that such an organization offers fairly adequate guarantees that a reasonable amount will be saved at any time from the national income and invested in the future. But it offers almost no assurance that under competition without governmental interference savings will be invested wisely from a social point of view, or even that progress will be carried forward in a manner which does not involve impairing vital future interests of society in the way of the long-run effects on its human and material resources.

Effect of government grants and subsidies

During the period of expansion following the Civil War down to, say, 1880, the railways of the United States were developed far beyond our needs, with serious consequences to our financial structure, evidenced particularly in the great panic of 1873 and the years of depression which followed. If the government had been less prodigal in granting lands and subsidies to railroads, we might have had a far better planned transportation system today, and at the same time there would have been less wasteful exploitation of forests involving irretrievable loss. Eventually the roads would have been built up to our needs by private initiative and private finance. The only justification of non-interference with private enterprise and its encouragement by subsidies from the government is that we have come to our industrial maturity more rapidly than we should otherwise have done. Whether this acceleration of growth was worth the price in what must seem a wasting of our heritage, is a moot question. Who can say what would have been the destiny of our country had it been a backward, agricultural nation, unable to profit by the flood-tide of industrial and commercial expansion which has carried it to a position of world dominance in the economic field since the outbreak of the Great War? What is apparent now is that this development having been secured, we can no longer afford the policies which tend to temporary stimulation of industrial growth at the cost of permanent loss of fundamental resources.

The advent of machinery killed personal relation in economic association

Perhaps the most unfortunate result of the advent of machinery is in destroying the personal relation between those who enter into the various economic relations. Industry is organized on the system known as "capitalism", where the ultimate owners have no interest in the business except their dividends, and never see the people whose labor makes their incomes possible. Likewise the man who does any piece of work has no thought of the stranger, perhaps in another state or even on another continent, who will consume his product. Even those with whom we do come into close contact in business are not persons to us, but merely industrial units; it is their money, what they have to offer us and on what terms, that does most of the talking. The cheap shop, built on the foulness and injustice of the sweating den, is sometimes the most garish and popular center of trade in a modern city.

At the present time there certainly is need for more State control in the interests of our people's future welfare. The movement in this direction is well under way, as we see from the multiplication of government bureaus and commissions, and the universal agitation for regulation and for increasing the power and efficiency of government. All this is well, yet the nation must beware of returning to the medieval idea of governmental direction and supervision. Before the war many people would willingly have seen our country emulate Germany, which, by an able system of coercive and directive regulation of all its national forces, had won so remarkable an amount of military power and industrial efficiency. While the war was a rude shock to those who had contemplated this political bureaucracy with approval, it did not bring home with full force its lesson with regard to industrial bureaucracy as a principle. The gradual weakening of the German war-machine was really not so much a commentary on the dangers of imperialistic government as it was on the baleful effects of industrial regimentation. The reliance

placed on a hard and fast régime of red tape, though it boded well at the outset, proved fatal in the end. The German war-machine was the martial counterpart of State socialism, and its disintegration but an emanation of a general stagnation which obtained in the entire officialdom, and which has since rendered the industrial rehabilitation of the country next to impossible. Bureaucracy was not invented in modern Germany; it has been tried in Anglo-Saxon lands; it was in vogue in England in the seventeenth century and most of the eighteenth. It has always been found to be momentarily successful but disastrous as a permanent policy, and was completely overturned by the industrial revolution.

The machine that has become a curse must be made a blessing

The invention of new systems of organization has aggravated the effect produced by the invention of new mechanisms of labor. The general result is that man has become the slave of the machine; and great have been the unsettlement, the unrest and the suffering. This has led Ruskin and his followers, such as William Morris and Elbert Hubbard and many of the Guild Socialists, to condemn the invention of the modern machine, and attempt to found again the ancient arts of the peasantry. It does not, however, seem likely that the old condition of things will ever be restored. Frankenstein will not destroy the strange monster of steel that he has set working. Practically speaking, it is now beyond his power to do so. Not less invention, but more invention, is needed. The machine which has destroyed so much of the past, and created confusion in the present, must be made to build up the future. If all goes well, the humblest farm laborer, a hundred years hence, will find himself in a happier position than even the upper classes of society were in a hundred years ago. For he will be the master of a metal slave, cheaply but strongly built, and driven by a cheap supply of power, which will free him from all the hard and brain-deadening part of his labors and win him leisure and the means for sweetening and liberalizing recreations. The enormous factory towns will again be resolved into little industrial groups, scattered over the countryside and partly reattached to the soil. And the great commercial cities will go on spreading for hundreds of miles, along motor-roads and high-speed railways, until they will be lost in the woodlands and the farmlands continually intervening between the clusters of red-roofed and white-walled houses.

We live in an age of transition between a dead world and one in travail

In other words, we are living in an age of transition between a dead world and a world still in travail of birth. Neither statesman nor prophet can of themselves get us out of the muddle into which we have fallen. Yet both can greatly assist, one by practising, and the other by preaching, the religion of true liberty. Our generation needs uplifting by another wave of inspiration, hope and enthusiasm. The popular mind must be touched again with a divine fire, and set to work with a renewed genius for invention in all the departments of national life. The task that the men of the eighteenth century partly accomplished must be carried to its full end in the next three generations. As the State does not invent, the State cannot help us here.

All that fosters individual initiative, with its innumerable experiments, enterprises and adventures; all that elicits from a man powers of mind that he did not himself suspect; all that shows how the manifold experiences and essays and insights of a free and law-abiding people can put to shame the well-thought-out plans of the most enlightened bureaucracy; all that justifies liberty of her children is needed to save the Anglo-Celtic race from falling by the way when its noble and mighty task is scarcely half carried through. We must show that the inventive power of a free people is more permanently effective than the organization for efficiency which the Prussian undertook to force upon the world. If we fail to do so, it may be many hundreds of years before liberty becomes

again the mightiest force in the world of actual affairs. No doubt the gospel of individualism was developed by our grandfathers to an extravagant degree. None the less, it was originally inspired by true feeling and sound knowledge. The feeling of the value of personal freedom, and the knowledge of the very grave disadvantages of continual State interference, were at the bottom of the general dissatisfaction with the governmental direction of the economic forces of nations which led in the eighteenth and nineteenth centuries to the establishment of the régime of individual liberty. And no doubt in turn the creed of freedom from restraint was overemphasized at many points, and an increased measure of control has become necessary to protect the interests of society at large and of its weaker members. But the general principle of freedom and individual initiative must be conserved and developed.

Advantages of a bureaucracy only in economy and speed of accomplishment

A capable and intelligent bureaucracy, armed with medieval powers of control over every department of a nation's activities, is undoubtedly a quicker and less wasteful method of getting particular things done than is the cumbersome process of agitation and final action through the agencies of public opinion. But what are the things that the bureaucracy will do so efficiently? Obviously it will have its own purposes and aims. And then what security have we that the purposes and aims of the bureaucracy will be those of the nation? No such guarantee has yet been found. Democracy is exasperatingly slow and bungling, but in the long run the people do get what they want, and not what some overlord wants for them, or even wants for himself. Those who clamor for efficiency are prone to pass lightly over the question of what is to be done efficiently. If we were agreed on the aims of government, the problem of the means of achieving them would not be so hard to solve. A good part of the wastefulness of our procedure is due to half-heartedness and groping as to the goal. To have efficiency in our administrative mechanism for accomplishing results already selected and agreed upon is desirable indeed, but efficiency in using the masses of the common people as pawns in some dynastic game of chess as means to ends not their own, but the ambitious schemes of some ruling house or ruling class — this does not look so attractive. Before we yield to the seductive gospel of administrative efficiency, we must at least make sure that we have safeguarded ultimate popular control, and then we must ponder well the question of what is really most efficient in the long run.

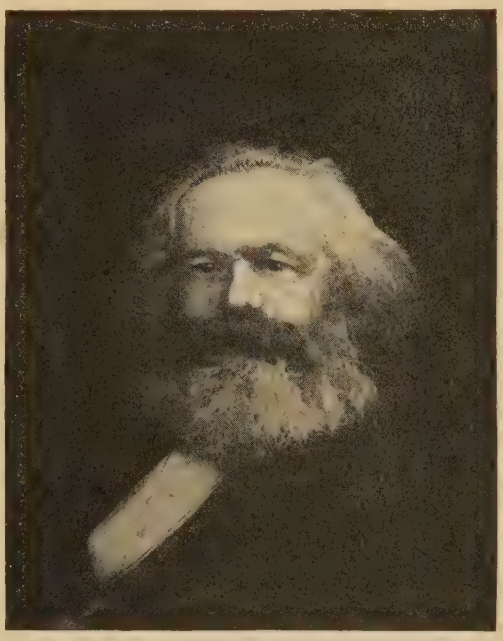
What socialism lacks. The deceptive lure of utopianism

In all ages there have been men who have felt that it would be possible to devise a social system in which inequality and oppression would be done away with, or at least greatly reduced in extent in comparison with the facts of the civilization about them, and have advocated the establishment of some such system. Sometimes they have appealed to the sentiment for humanity and efficiency of a despot or ruling class, sometimes to the self-interest of the masses, who would be the chief beneficiaries of the change. Sometimes this latter appeal has taken the form of incitement to violent revolution and the overthrow of the "tyrants" of the possessing classes, sometimes that of exhortation to peaceful transformation by constitutional methods. The "orthodox" or "scientific" socialism founded by Karl Marx and Friedrich Engels in the second half of the nineteenth century has generally been interpreted as taking a more or less fatalistic attitude, resting in the belief that the irresistible forces of economic law would in a fairly short period of time defeat the capitalistic and competitive organization of economic life through the development of monopoly which would force society to step in and assume control. The policy advocated on behalf of the working population has been that of perfecting the machinery of democratic control, especially securing universal suffrage, which had not been generally granted in Europe at the time Marx and Engels

wrote, and leaving the details of economic organization to be worked out "after the revolution".

It is obvious, however, that any reasonable hope for success under socialism depends on concrete thinking and planning and constructive preparation, that is, upon "utopianism", toward which the "scientific" socialists took a rather contemptuous attitude. The result has been the development of divergent tendencies in the radical movement, to get away from Marxianism or to reinterpret its doctrines. This development was stimulated by the failure of universal suffrage, when achieved, to effect a more equalitarian régime in economics, and by the manifest failure of "economic law" to bring about quickly the intolerable state of affairs which the socialists had counted upon to force a general change of social economic basis. Consequently, those who looked toward a radical change in social arrangements were forced back upon the concrete problems connected with improvement, upon "utopianism", again.

The radical labor unionism or "syndicalism" which developed rapidly in France in the decade before the outbreak of the Great War was a notable form of utopianism in that it represented a fairly definite plan, not only for securing control of economic life by the "workers", but also for the operation of industry after labor should come into power. The machinery proposed for carrying out both these tasks was that of the "One Big Union", made familiar in America by the I. W. W., which is the American expression of syndicalism. The war, which was to bring about a better world order and make the world "safe for democracy", gave a tremendous impetus to the growth of all sorts of liberal sentiments, and at the same time tended still further to discredit the older or orthodox socialism. The latter had stressed internationalism as one of its fundamental doctrines and of course this failed egregiously in the crucial test. In addition, the war forced a tremendous development of State control, toward which the older socialism chiefly looked as an instrument of reform, and the results were generally unsatisfactory to the working classes. Then, too, the successful Bolshevik revolution in Russia, carried out at little cost and without waiting for the slow evolutionary processes contemplated by Marx and Engels, was especially effective in giving a finishing blow to their doctrine, though the Bolsheviks claimed that they were the true heirs and correct interpreters of Marx. The system based on "soviets", or workers' councils, set up in Russia is similar to the One Big Union idea, and its success in getting and holding the supreme political power made this for the time being the dominant form of utopianism.



KARL MARX

But although the war led to a great strengthening of labor organizations in Great Britain and America as well as in other countries — partly on account of the liberal sentiments inspiring its fundamental objective in the Allied countries, and partly because the State found it necessary to keep peace with labor in order to stimulate production — organized labor in the English-speaking world retained the rather conservative temper which has always characterized it in comparison with other countries. No form of socialism or syndicalism has ever succeeded in enlisting

the sympathies of a large fraction of the wage-earning people of Great Britain or any of the British Dominions, or of the United States, and probably the greater part of the strength which these movements do command in those countries is derived from other social classes. In other countries the socialist party or parties command the allegiance of the wage-earners. In the Anglo-Saxon world the workers are either adherents of the more conservative "bourgeois" parties or else tend to the formation of "labor" parties which are distinctly opportunistic and not revolutionary in their social philosophy and political aims, — all to the great disgust, it is hardly needful to observe, of the propagandists for the radical movements in question.

The strength of socialism really derived from other classes than the labor

In a sense the disgusted spokesmen of radicalism are doubtless right; it could not be maintained that the conservatism of the working population, or their failure to form coherent political groups standing definitely for their special interests, is due to any intelligent, thought-out conception of either their own or their country's welfare. And the growing appeal of socialism to many earnest and thoughtful persons is a fact which cannot be denied. Dazed by the waste of life and the suffering and disorder woefully patent in our industrial civilization, they see in the nationalization of all the resources of existence and in the governmental control of all industrial activities the only permanent remedy for the poverty and the drifting misery of our dark and troubled age. Socialism of some sort or another is coming to have almost the power of a religion over some fine and eager minds. There is much sympathy with socialistic ideals among the brightest and best of the younger generation in our schools of all grades, and the same is true of those castles of tradition, the English public schools and universities.

In itself it is a good sign that the sons of the governing classes are being largely moved by sympathy with the troubles of the working people. A real quickening of the social conscience — the general social conscience — is the most vital necessity of modern civilization. One of the chief disasters of the industrial revolution is the gulf that it has made between the social classes. Many able publicists have been distressed by the tendency to the establishment of a new form of feudalism marked by most of the evil features, and lacking most of the good ones, of the system which obtained in Europe in the Middle Ages. The modern absentee capitalist, owner of a factory or mine, resembles a French nobleman of the old régime. He knows personally nothing about the workmen who help to earn the dividends on which he lives. All that he knows is that when they strike for higher wages they are striking for a reduction in his income. What is needed, therefore, is a large, quick and general sympathy between the multitude of small anonymous capitalists who are only sleeping partners in the manifold industries that they supply with funds, and the vast army of unknown workers who, ranged under foremen and managers, have lost all sense of human relationship with the shareholding class for which they are really laboring. In so far as the spread of socialistic ideas among the younger generation of well-to-do people serves to stir the imagination and touch the feelings of the shareholders of the future, the gospel of socialism prepares the way for industrial reforms.

The need for industrial democracy. The danger of socialism

But this tendency involves a serious danger which society must by all means strive to avoid. It is easier and more pleasing to those who have industrial power and who become sympathetic with the toiling masses to attempt to improve and elevate them from above and without, than it is to give them opportunity and encouragement to help themselves. This is the feudalistic tendency which is perhaps as bad, possibly worse at the last, than social stratification and oppression. It is a short-sighted policy, and will not work in the long run. Freedom carries with it, of course, the freedom to make mistakes,

and if the ignorant and depressed classes are suddenly given an increased measure of power, it must be expected that it will not always be wisely used. Yet in the interest of society as a whole, even more than that of the toiling masses themselves, this is what must be done. Only by the use of power, indeed only by making mistakes in its use, can they ever develop responsibility, self-respect and competence. The labor movement in all countries, especially in England and somewhat more tardily in America, is waking up to this fact and shifting the emphasis in its contentions from the mere matter of wages and hours to the larger question of a voice in the control of industry.

The lack of originality under a bureaucratic system

The danger from the social point of view is well illustrated by what happened in Germany. The great German revolutionary genius, Ferdinand Lassalle, succeeded in arousing the interest of Bismarck, who then wielded the political power of the rising German Empire. The result was that the State undertook to improve the lot of its working people and created a great scheme of industrial organization which not only raised the standard of comfort of the wage-earning class but rapidly brought Germany to the front as a competitor in world industry and trade. But instead of making the workingmen contented, the new policy led directly to the greatest development of revolutionary socialism the world has seen. Everything was to be done for the workingman, nothing to be done by him. Initiative was no more wanted in a workman than in the private soldier of the German army. The final result we have already discussed; when Germany was put to the supreme test her wonderful system was marked for failure.

The fact is that too rigid a regimentation of the social and industrial activities of a race naturally impedes the general inventive genius. Even when a bureaucratic government is sufficiently enlightened to allow scope for scientific enterprise, officialism stays the free and large progress of human powers. This is illustrated by the inventiveness of the German workmen who have come to America, in contrast with their unproductiveness at home. Since Mergenthaler constructed his first linotype machine in 1884, the immigrant German artisan has contributed a large share to maintaining the faculty for labor-saving inventions that has distinguished America from all other nations.

Another illustration may be drawn from English experience in the field of electrical engineering. Full of enthusiasm for the future municipalization of large electrical enterprises, Parliament imposed restrictions on the private operation of street railways and lighting plants. The result was to crush all enterprise in regard to the supply of electricity. For, in order to advance the municipal control of the new force in industry, promoters of electric-supply undertakings were allowed only twenty-one years' interest in their property. In consequence no capitalist would provide money for undertakings with so short a tenure. It was not until the passing of a new law, in which the period of twenty-one years, after which the undertaking was subject to purchase without any allowance for good will, was extended to forty-two years, that the problems of the industry were energetically attacked by inventive minds, backed with adequate funds by enterprising capitalists.

The socialist difficulty: hopeless conservatism

In the meantime, American engineers and inventors, having been able freely to compete with each other for the full rewards of invention, had obtained the lead in many branches of electrical science. So at the close of the nineteenth century the British public had to witness the humiliating spectacle of their municipal authorities being forced to import from the other side of the Atlantic the electrical apparatus and even the steam engines specially used for street railway purposes.

Behind any kind of socialistic organization there is always an official, and an official is a man who does not take risks.

He waits to see if a thing is a great success elsewhere before he advises its adoption. An enterprising capitalist, on the other hand, is able to take up a dozen new ideas and put them to the test; for one brilliant success will more than pay for all the failures. It has been well said that the true friend of inventive progress is the rising competitor in a busy hive of industry where the difficulties of securing a profitable footing are very considerable. Such a man is ever on the watch for an opportunity to gain some leverage by which he can raise himself to a level with richer and more powerful rivals. If he is a good employer, his workmen enter into the spirit of the competition, feeling that promotion may follow on any services they may render. They may even possess themselves some talent for invention, or they may do greater service by recognizing the flame of genius in others, and coöperating in their work. It is thus that successful inventions are usually started on their useful careers.

The advocates of socialism often point to what has been done in the nationalized postal service and the administration of telegraphs, telephones and railways in certain European countries. But the State did not invent the telegraph and the telephone and the locomotive. It has merely appropriated the hard-won achievements of inventors and of enterprising men of means who backed the inventors at a time when the public was often inclined to ridicule and impede the working out of the new ideas. If the first inventor had gone to some governmental or municipal official with a proposal to spend hundreds of thousands of dollars in testing and developing his new instrument of power, he would have been politely dismissed. But when, after years of labor and costly experimentation, the outlay of perhaps millions of dollars of private wealth has created some large new force in civilization, the official mind is ready, and even eager, to take over the accomplished success. Then very often it uses the monopoly which it has seized as a weapon of unprogressiveness to keep all private competitors from the field of enterprise in which they could, in free and open battle, win their way again to the front. In general, students of these problems are pretty well agreed, the State should not take over an industry until its equipment and technique have been pretty well developed and fixed by experimentation under the stimulus of private initiative and the pressure of competition.

What socialism appears to lack, then, is progressiveness. It can organize, but it cannot create. There is an element of paradox in this situation. The striking out of new lines is largely a gamble, and one might naturally suppose that an official in control of the resources of society would be disposed to experiment recklessly, since the loss in case of failure would not fall upon himself. But it does not work out in this way, and a little consideration will make the reason clear. The official thinks in terms of his job, and the way to be surest of that is to play safe. For democracy itself, the opinion of the masses, is tremendously conservative. This is the lesson which political thought is very reluctant to learn, but it is unquestionably the truth. The weakness of socialism is not irresponsibility but lethargy and stagnation. It cannot produce a social organization with the scope and the stimulus for creative minds which are necessary for the development of the full powers of the human race. In order to change the world for the better, there must be left room and opportunity and means for carrying out the changes. Especially is this the case in regard to the development of fresh and larger powers of control over natural resources. The great need is for new ways of doing old things and new ways of doing new things. These advances are not to be obtained by any system of official control over industrial activities that prevents men with creative minds from breaking their way through all traditions and privileges and social arrangements. Competition is here the great force of progress. It may often involve in ruin the persons who show a want of enterprise, but on the ruin of their fortunes a new group of more inventive and more adventurous men rise into wealth and power.

ASTRONOMERS III

SIR GEORGE DARWIN—WHO REVEALED THE EARTH'S MOTION BY CALCULATION
JEAN BAPTISTE JOSEPH DELAMBRE—HISTORIAN OF ASTRONOMY AND AUTHOR OF THE TABLES OF URANUS
JOHANN FRANZ ENCKE—A CALCULATOR OF PLANETARY ORBITS
ERATOSTHENES—EMINENT ASTRONOMER IN THE TIME OF THE PTOLEMIES
EUDOXUS—THE BRINGER OF ASTRONOMY FROM EGYPT TO GREECE
JOHANN FABRICIUS—A STUDENT OF SUNSPOTS
HERVÉ AUGUSTE ETIENNE ALBANS FAYE—DISCOVERER OF FAYE'S COMET
CAMILLE FLAMMARION—THE POPULAR ASTRONOMER OF FRANCE
JOHN FLAMSTEED—ASTRONOMER ROYAL

SIR GEORGE DARWIN

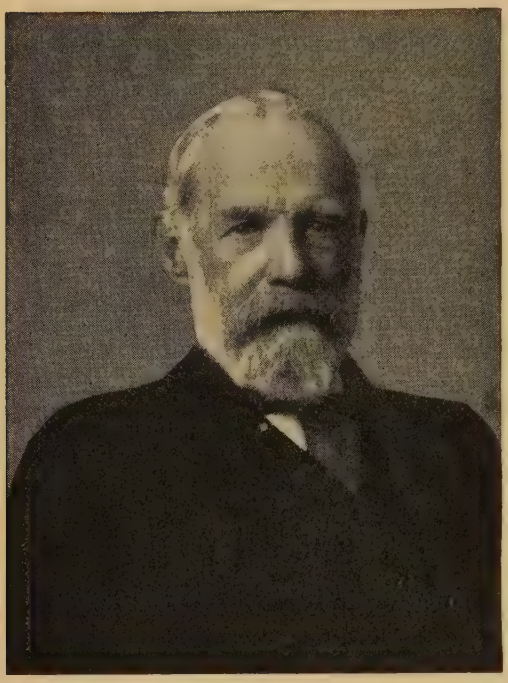
Who Revealed the Earth's Motion by Calculation

SIR GEORGE DARWIN was born at Down, in Kent, England, on July 9, 1845, the second son of Charles Darwin. He was graduated from Trinity College, in Cambridge, in 1868, and in the same year was elected to a fellowship. He was admitted to the bar in 1874, but, not having the physical health necessary for that life, soon returned to Cambridge, and devoted himself to the profoundest mathematical problems of astronomy. He had already published a statistical inquiry into the effects of the marriages of first cousins, but his numerous scientific papers now dealt chiefly with problems of the mutual effects of celestial bodies revolving round one another, with the evolution of the solar system, and specially with the history of the relation between the earth and the moon. He was not an astronomical observer; his work consisted of abstruse calculations made in his study. In 1883 he was appointed Plumian professor of astronomy and experimental philosophy, and was reëlected, in 1884, a fellow of Trinity.

His name is principally associated with the mathematical investigation of tides, their laws, and their effects. The problem of tides had already attracted the attention of Newton and Laplace, and Lord Kelvin had devoted much time to the subject before Darwin took it up and elaborated it to a point far beyond any which his predecessors had reached. Throughout all his work on tides he was closely associated with Kelvin, to whom he dedicated the collected edition of his scientific papers.

Aside from its practical value, this tidal study had its astronomical value, as affording insight into a factor which Darwin has taught us to regard as of great importance in cosmic evolution. It had been recognized since the days of Kant, who was the first to draw attention to the matter, that tidal friction must act as a brake, retarding the rotation of the earth and thus lengthening the day. But it was evident also, since action and reaction are equal, that the loss of energy occasioned by tides must be borne in part by the tide-raising body—in our case, the moon—and that its orbit must be in course of time affected.

Sir George Airy also had worked a good deal at this problem with little result, but Darwin was able to show, by graphical methods of his own devising, that the moon is, up to a certain point, gradually driven away from the earth by these tidal effects; and was able to estimate that fifty-seven million years ago the moon and the earth formed one body, rotating in five and a half hours. This estimate, however, was based on the assumption that the earth is or was previously a viscous body, whereas the more modern observations and investigations of scientists, notably those of Michelson and Gale (1913), prove that the earth is certainly not viscous now, and seem to indicate that it never was in a viscous state.



SIR GEORGE DARWIN

He published, in 1901, an admirable popular work on tides and their effects in the solar system. His "Collected Scientific Papers" were published in 1907 to 1911. Sir George Darwin was President of the Royal Astronomical Society and of the British Association. He died at Cambridge on December 7, 1912.

JEAN BAPTISTE JOSEPH DELAMBRE

Historian of Astronomy and Author of the Tables of Uranus

JEAN BAPTISTE JOSEPH DELAMBRE, French astronomer, was born at Amiens on the 19th of December, 1749. He studied first under the Abbé Delille, and afterwards in Paris, where he took a scholarship at the College of Plessis. Poverty obliged him to turn tutor, and while acting in this capacity to the son of the receiver-general of finances he attended the lectures of Lalande, who influenced Delambre's employer to build an observatory for him at his own residence. In 1790 he worked out the tables of Uranus and gained for his calculations the annual prize of the Academy, of which body he was elected a member two years later.

Soon after Delambre commenced the construction of new solar tables, and at a still later period tables of the motions of Jupiter and Saturn. Along with Méchain he was appointed by the French government to measure the arc of the meridian extending from Dunkirk to Barcelona, and published a detailed account of his measurements in "*Base du système métrique*" (3 vols., 1806, 1807, 1810), for which he received the decennial prize of the Institute. In 1807 Lalande died, and Delambre was appointed to the vacant chair of astronomy at the Collège de France; and treasurer to the imperial university until it was suppressed in 1815.

Delambre received many honors during his lifetime: he was member of most of the learned bodies of Europe and an officer of the Legion of Honor. His last years were occupied in studies in the history of science, in which he published "*Histoire de l'astronomie ancienne*" (2 vols., 1817); "*Histoire de l'astronomie au moyen âge*" (1819); "*Histoire de l'astronomie moderne*" (2 vols., 1821); "*Histoire de l'astronomie au dix-huitième siècle*" (1823–27). He wrote besides: "*Tables écliptiques des satellites de Jupiter*", "*Méthodes analytiques pour la determination d'un arc du meridien*", "*Tables de soleil*", "*Astronomie théorique et pratique*," etc. Besides these he wrote a number of excellent memoirs.

Delambre died at Paris on the 19th of August, 1822.

JOHANN FRANZ ENCKE

A Calculator of Planetary Orbits

JOHANN FRANZ ENCKE was born on September 23, 1791 at Hamburg, Germany, where his father was a clergyman. He early specialized in mathematics and studied at Göttingen, under Gauss. In 1813 his studies were interrupted by the call for men to serve with the Hanseatic Legion in the war. Encke at once enrolled, and served at the front, becoming a lieutenant. When peace was declared he returned to Gauss and astronomy, but Napoleon's escape in 1815 called all back to the colors, and he proceeded to Berlin. Here he met Bode, who remained his friend all his life.

In 1816 Encke was appointed to the Seeberg Observatory as assistant to Lindenau, and from 1817 to 1818 was in charge of all the work of the observatory during the latter's absence. In 1820 he was appointed vice-director, and in 1822 director at Seeberg; in 1825 he was made director of the Royal Observatory at Berlin as successor to Bode, and secretary of the Academy of Sciences.

Encke's great work was the computation of cometary orbits, and other computations no less valuable to astronomical science. These were his delight, and in order to be free to devote himself to observation and calculation he refused three offered professorships — at Greifswald, Jena and Marli. The most famous of his computations was the orbit of the comet discovered by Pons in 1818, for which he determined an elliptical path occupying $3\frac{1}{3}$ years, and identified former appearances in 1805, 1795 and 1786. These calculations made him famous, and the comet became known as Encke's Comet. On each return after this, Encke predicted the time of perihelion passage, and found each time that the comet's pace had accelerated somewhat, from which fact he concluded the existence of a resisting medium in space. This hypothesis, however, is not accepted generally by astronomers. Many other cometary orbits were computed by him.

Another important piece of work which Encke carried out was the computation of the sun's distance much more exactly than it had been computed before. Greater accuracy has since been obtained, but his results were of great value. They were derived from careful observation of the two transits of Venus in 1761 and 1769, and were published in a treatise, "The Distance of the Sun". He computed also the mass of Mercury and the movements of some of the asteroids.

In 1864 Encke retired from the Berlin Observatory, his health being much impaired. He lived a retired life at Spandau until his death on August 26, 1865. Encke was twice honored by the Royal Astronomical Society, which awarded him its gold medal in 1823 and again in 1830.

ERATOSTHENES

Eminent Astronomer in the Time of the Ptolemies

ERATOSTHENES, Greek astronomer, geometer, and scientific writer, was born at Cyrene about 275 B.C., and studied at Alexandria under Callimachus, the celebrated poet and grammarian. From Alexandria he was attracted to Athens by the philosophical teaching of Ariston and Arcesilaus. In 240 B.C. Callimachus, who had been librarian to Ptolemy III Euergetes for twenty years, died, and Eratosthenes was appointed in his place. For the remainder of his life he was occupied in a variety of studies, writing in verse and prose on astronomical, literary, philosophical and historical subjects until, as an old man of 80, his sight failed him and it is said that rather than become blind he starved himself to death.

Eratosthenes was one of the most learned men of antiquity: his contemporaries bestowed on him the title of *Beta* as being second in all branches of learning, if not actually first in any. He wrote a commentary to Plato's "*Timæus*" and a great work in a dozen books "On the Old Comedy", dealing with theaters and theatrical proprieties and discussing the works of the comic poets themselves. It is, however, by his attempt to measure the size of the earth and by his geographical studies that Eratosthenes is most famous. He endeavored to determine the obliquity of the elliptic by measuring the distance between the tropics, and, considering the means of observation and knowledge of the time, his error of about $7'$ is extremely small. To calculate the circumference of the earth he adopted the means employed at the present day, but we cannot tell how accurate the results because his computation is in stadia and we do not know the length of the stadium he used. He knew the world is round. Eratosthenes was the founder of scientific chronology: he tried to fix the dates of the main events in literature and in history from the time of the fall of Troy. His poem "Hermes", giving a legend of the stars and zones, has been preserved, and his "Geography".

EUDOXUS
The Bringer of Astronomy from Egypt to Greece

EUDOXUS of Cnidus was born in that town about 400 B.C. He early imbibed the learning of his day in all its branches, including philosophy, medicine, astronomy and mathematics. Astronomy he learned from the priests of Heliopolis during a stay of about a year and a half in Egypt. On his return he founded in Cnidus a school and an observatory, and introduced to the Greeks the knowledge of the true length of the solar year, which had been known to the Egyptians for many hundreds of years. This length, $365\frac{1}{4}$ days, was introduced into the Julian Calendar.

Eudoxus is famous as the inventor of the theory of concentric spheres, by which he sought to reduce to harmony the complicated motions observed in sun, moon and planets. This he did by ascribing to each body a set of spheres, moving with uniform motions, the observed motion of the body being the resultant of these composites. The center of each sphere lay in the surface of the preceding one. To the sun he ascribed three, to the moon the same, and to each of the planets four of these spheres. His theory was adopted by Aristotle and many teachers, and more and more spheres were added as further complexities were discovered in the motions of the heavenly bodies. The resultant confusion of this imaginary plethora of spheres was swept away by the establishment of the Copernican system.

Eudoxus is known to have made many observations of Canopus, and to have estimated the diameter of the sun in terms of the moon. This last he placed at the ridiculously low estimate of nine times, but even that was an extraordinary advance on prevailing notions.

He is credited with the invention of an instrument for measuring time, which consisted of such a complicated network of lines that it received the name of the "Spider". He is known to have written a good many treatises on astronomical and other subjects; two of these were embodied in poems by Aratus, and their substance has thus been preserved — the "Phenomena" and the "Mirror", the latter dealing with the constellations. Other fragments have been preserved in the writings of Hipparchus. Attempts have been made to use the writings thus transmitted secondhand to compare the sky now with the sky then; and there is no doubt that a remarkable similarity is confirmed, though the indefiniteness of the early writers does not permit the comparison to be made in great detail. Aristotle has given us some idea of the philosophical views of Eudoxus, which consisted chiefly in a belief in the supreme value of pleasure, without, however, any clear differentiation between pleasures of higher and lower kind. Against this view Aristotle argued, while paying a tribute to the sincerity with which Eudoxus advanced his opinions. Eudoxus is believed to have died about 356 B.C.

JOHANN FABRICIUS
A Student of Sun-spots

JOHANN FABRICIUS was born at Osterla near Norden in East Frisia, his father, David Fabricius, being pastor of that place. David was himself an amateur astronomer of considerable repute, and had spent some time as a young man at Uranienburg with Tycho Brahe. As a pastor, astronomy was still his recreation and took up much of his time; and his son early imbibed this taste for observation.

David Fabricius was too poor to buy astronomical instruments, but constructed several for himself, including a sextant and a quadrant; and Johann as a young man learned in Holland the art of telescope construction. In 1610 he turned his telescope upon the sun, and observed the phenomena of sun-spots. The honor of their first discovery is claimed for him as well as for Galileo, Scheiner and Harriot. But "the real credit lay with the telescope, so that the question of priority is of no importance." Johann Fabricius, however, was the author of the first book dealing with sun-spots. This was brought out in 1611. It was considered by Lalande of sufficient importance to be reprinted in a memoir of the French Academy of Sciences in 1778.

David Fabricius, the father, has no rival as the first discoverer of the famous and beautiful variable star Mira, or *o* Ceti, in 1596.

The date of Johann's death is not known. The only certain fact is that he was still alive in 1617, the year of his father's death. David Fabricius was killed by a peasant whom he had publicly rebuked as a thief.

HERVÉ AUGUSTE ETIENNE ALBANS FAYE
Discoverer of the Comet that Bears his Name

HERVÉ AUGUSTE ETIENNE ALBANS FAYE, the discoverer of the periodical comet which now bears his name, was born at Saint-Benoît-du-Sault (Indre) in 1814. He studied at the École Polytechnique, but left it to accept a position at the Paris observatory to which he had been appointed, on the recommendation of Arago. But at a later date when rendered famous by his discovery, he returned to it as professor of geodesy (1848–1854). On November 22, 1843, he gained the Lalande prize, membership in the Academy of Sciences and the attention of the world by his announcement of the Faye comet. This comet belongs to the class of 40 periodical comets, whose periodicity has been established by the fact that their return has been actually observed. The Faye comet made its last perihelion passage in 1917 (its tenth reappearance after its discovery), its period being 7.41 years.

In 1854 Faye became director of the academy at Nancy and professor of astronomy; in 1862 a member of the bureau of longitudes, and its president in 1876. The next year he was appointed chief inspector of higher education, and Minister of Public Instruction. The latter years of his life were devoted to astronomical investigation, and the publication of the results of his work which covers a large field in that science. In addition to papers contributed to scientific journals he published "*Parallaxe d'une étoile anonyme de la Gr. Ourse*" (1846), "*Anneaux de Saturne*" (1848), "*Déclinaisons absolues*" (1850), "*Sur L'Origine du Monde*" (1884), and "*Nouvelle étude sur les tempêtes, cyclones, trombes ou tornados*" (1897). He died in 1902.

CAMILLE FLAMMARION
The Popular Astronomer of France

CAMILLE FLAMMARION was born at Montigny-le-Roi, in the Department of Haute-Marne, on February 25, 1842. At first intended for the Church, he was educated at the Ecclesiastical Seminary at Langres, but the love of astronomy took hold of him, and he never seriously began his studies for the priesthood. At the age of sixteen he became assistant to Le Verrier, and remained four years at the Paris Observatory. He then qualified for a post in the *Bureau des Longitudes* by a year's study in mathematics at the Sorbonne. From 1863 to 1867 he held this office, editing at the same time the journal *Cosmos*, and from 1865 the scientific section of the *Siècle*.

In 1882 Flammarion founded the paper *L'Astronomie*, and in 1887 promoted the *Société Astronomique de France*, of which he was the first president, and afterwards secretary. Since 1867 he has delivered many lectures on astronomy, which are as interesting and popular as his books. His many writings are characterized by a fervid and highly colored style. He is carried away by a kind of rapture in the contemplation of immensity and of the insignificance of human destiny which that immensity conveys to him. His books owe their wide popularity partly to this literary quality, but also to their clear presentation of scientific facts.

Camille Flammarion is an experienced practical astronomer. In 1883 he built his own observatory at Juvisy-sur-Orge, where many observations of great value have been made. His most important work has been in connection with double stars, and with "star-drift", a phenomenon pointed out by Proctor. He has computed the periods of many binaries, and has shown that many supposed double stars are merely optical pairs. These last formed a long list presented to the French Academy in 1878. Between 1873 and 1877 he investigated the motions of a great number of double stars in relation to the theory of star-drift, or of systems formed by stars at a great distance

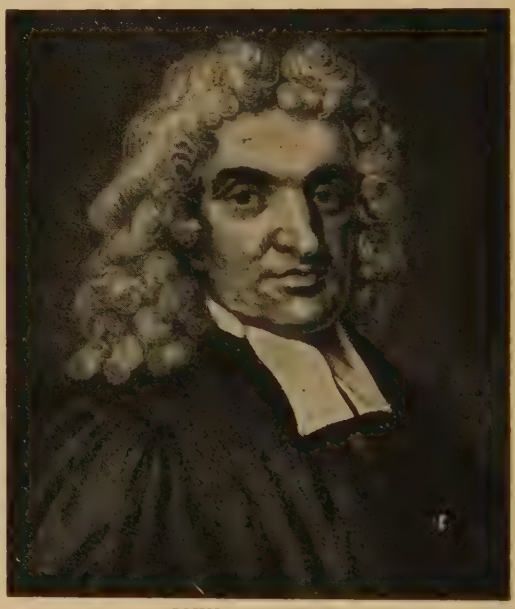
apart, and the results were published in a "Catalogue of Double and Multiple Stars in Certain Motion" (1878). Other investigations have included variable stars, of which he compiled a comprehensive catalogue from the catalogues of all ages; the planets Mars, Jupiter and Saturn; the moon; and the aurora and other problems of terrestrial magnetism. His books include "Marvels of the Heavens", "The Atmosphere", "Omega, the Last Days of the World", "Popular Astronomy", "The Unknown" and "Astronomy for Amateurs", all of which have been translated into English.

JOHN FLAMSTEED
First Astronomer Royal of England

JOHN FLAMSTEED, first British Astronomer Royal and author of a famous catalogue of stars, was born at Denby, near Derby, England, on August 19, 1646. He was sent to school at Derby, but his education was cut short at the age of sixteen by severe rheumatism, for which many cures were tried in vain. Thus kept at home, he took to the study of astronomy, poring over old books and making observations with a rude, home-made quadrant. Finding that the moment of an eclipse of the sun, which he observed in 1668, differed greatly from the time predicted, he took up astronomical calculations, and in the following year a paper of his on that subject was published by the Royal Society in their "Transactions". In 1670 he entered Jesus College, Cambridge, and here came to know Newton. His observations of celestial bodies continued throughout his undergraduate days and were directed chiefly to the movements of the moon and the orbits of Jupiter's satellites.

Having been graduated in 1674, he was placed on a commission to report upon a proposed method of finding the longitude at sea, and his work in this matter led to his appointment by Charles II, in 1675, as astronomical "observator". His instructions were to study the motions of the heavens and the places of the fixed stars, with a view to perfecting the art of navigation. An observatory, designed by Sir Christopher Wren, was built in Greenwich Park; and, having been ordained as a clergyman in 1675, Flamsteed took up his work as Astronomer Royal in the following year, at the salary of £100 per annum.

Flamsteed was a man of hot temper, and very difficult to get on with, but he was a scrupulous and hard worker. In the following thirteen years, though very poorly supplied with instruments, he made twenty thousand observations of star positions which enabled him to publish the first Greenwich catalogue containing the places of three thousand stars. His position was improved, however, in 1689 by the revenues of a living with which he had been presented, and he was able to set up a mural arc of seven feet radius with which more accurate work was possible.



JOHN FLAMSTEED

He was for a long time on very good terms with Halley, to whom he was of much assistance, but their relations were finally severed by a quarrel over the publication of Flamsteed's observations. They were published in 1712, under the title of "*Historia Cœlestis*", and Flamsteed, who had not brought the work to the completeness which he desired, regarded this as an injustice to himself. An amended edition was printed later, part of it finished before his death, on December 31, 1719, and the rest completed by his assistant.

A FACTOR IN NATIONAL PROGRESS

Food, the Basis of our Physical,
Mental and Moral Well-Being

WHAT MAKES A NATION'S GREATEST ASSET

THE subject of household science includes three main divisions: Food, Shelter, Clothing. Shelter and clothing are of great importance to the comfort and development of the individual, but undoubtedly food is the most vital factor of the three. Many have the idea that food is simply something to eat to satisfy one's sensation of hunger, and so we find people living largely on bread, and coffee or tea with small amounts of other foodstuffs — usually highly-flavored and ready-to-serve foods. Fortunately, or unfortunately, these people continue to exist for years and therefore people do not realize the serious results of such a dietary and how such feeding militates against national progress. In every part of the world there are many people who go through life, from the cradle to the grave, with the handicap of a poorly-nourished body. A nation's greatest asset is not its mineral wealth, or similar resources, but its healthy citizens; and especially its healthy, normally developed, physically and mentally strong boys and girls — its future citizens.

Food is undoubtedly the fundamental basis of our physical well-being. This does not, however, complete the story, for, as we shall see later, mental well-being is to some extent dependent on the physical, as is also moral development. In a living body there is not only a constant wear and tear which necessitates continuous building up, but the mere fact of living necessitates a never ceasing expenditure of energy — every movement of the body burning up a small but definite amount of fuel food. Now while the human body may be regarded as a "self-building, self-regulating and self-repairing engine", it can neither repair nor make bone and muscle without the necessary material. Food is the only known source of such material that the body can use.

If lumber is the only material available, one cannot build a brick house — bricks and mortar are necessary. Similarly it is impossible to build the human body unless the constituents needed for blood, bone and muscle are provided. The body has the power of taking certain complex substances and, by means of digestion, breaking them down into more simple compounds, and then recombining them in a variety of ways to form the many complex substances found in the body; but while the human body can synthesize very complex compounds from simple substances, it cannot change one element into another. For instance, the body cannot produce iron from calcium, or calcium from sodium. Unless calcium is provided in sufficient amount, there will be a calcium deficiency; unless iron is adequately supplied, a lack of the necessary iron, and so forth.

It might be said that it is the right of every individual, and especially of every child, to be adequately fed, but the prevalence of malnutrition in every part of the country, and in the homes of the rich as well as among the poor, forces one to admit that, owing probably to ignorance, carelessness or poverty, many are living on a faulty diet and the one responsible for the dietary is thus perhaps unknowingly helping to retard the progress of the

nation. If this condition is to be remedied knowledge is necessary; one must know the needs of the body, to what extent each food supplies the requirements, the limitations of each food, etc.; and a consideration of some of the common dietary faults may also help to correct them.

A dietary deficiency in fuel food is very usual among under-nourished people. The various needs of the human body for energy have been discussed in the section Health, also the measurement of the energy or fuel value of foods in terms of calories. It is possible to supply enough building food and at the same time have the diet deficient in energy or fuel value. Interesting investigations as to the effect of such a diet on young cattle have been conducted by one investigator and very striking results found. If the young animal was fed sufficient food for normal growth, he found the increase in the width of the animal's chest to be approximately equal to the increase in length of the foreleg; while if the caloric value of the diet of the healthy, young animal was restricted so that growth was retarded, the length of the foreleg continued to increase at a fairly normal rate, but there was comparatively little increase in the width of the chest — the rate of increase of the latter being only about one-third that of the foreleg. When the energy value of the diet was further decreased so that, while the food supplied, still contained sufficient building material, the total energy value was barely sufficient to maintain body weight with no extra allowance to provide for any growth, the young animals lost weight but for a time continued to increase in height evidently at the expense of body tissue. On this diet the increase in the length of the foreleg was eight times as much as the increase in the width of the chest. This increase in height did not of course continue indefinitely on an insufficient diet, but it continued long enough to show definitely that the growth in height is out of proportion to the increase in width. A glance at many under-nourished children reveals this condition and leads us to believe that their diet is probably lacking in total calories or energy units. Another investigator working on the effect of restricted diets on cattle, especially the effect on the muscle tissue, found that when the diet was somewhat restricted the muscle fibers decreased about 10 per cent in diameter and also in length. In one case the diet was not sufficient for maintenance and after ten months of partial starvation the muscle fibers measured both in diameter and in length only about 40 per cent of their original size.

The total caloric or fuel requirement varies with the individual and with the life of the individual — especially with the amount of muscular work done. It is possible to estimate each individual's caloric requirement by using factors obtained as a result of respiration calorimeter, or respiratory experiments, but for general purposes probably the easiest method of telling whether the total fuel value of the diet is or is not satisfactory is to consult a standard table of weight as compared with height and age. A standard table can give only average weights and therefore a certain variation from the standard must be considered normal. With children a variation of from 7 per cent below to 10 per cent above may be taken as normal; 10 per cent below denotes undernutrition. Judging from the vital statistics of life insurance companies, young people of from fifteen to thirty years of age might better weigh slightly above the average, even to 10 per cent above, rather than below; while people who have passed that age might better weigh slightly below the average — only a trifle below in middle life, the amount tending to increase somewhat as one advances in years. Some insurance companies state it in this way: the normal weight for a person over thirty is the average weight, depending on build, for that person at thirty. For instance, in the following table a man of thirty whose height is 5 feet 10 inches should weigh 161 pounds; that then would be his normal weight for adult life. Taking the above into consideration, a variation of from 10 to 15 per cent below the average up to a pound or two above it may be considered normal for people over thirty years of age.

The following tables were prepared by the Association Life Insurance Directors and Actuarial Society of America in 1912, from the records of accepted applicants for life insurance in the United States and Canada. The height includes shoes and the weight clothing. Height without shoes would be one inch less for men and one and a half inches less for women; weight without clothing ten pounds less for men and six pounds less for women.

HEIGHTS AND WEIGHTS FOR MEN AT DIFFERENT AGES

(Based on 221,819 accepted applicants for life insurance)

Height	15 Yr.	20 Yr.	25 Yr.	30 Yr.	35 Yr.	40 Yr.	45 Yr.	50 Yr.	55 Yr.
5 ft. –0 in.	107	117	122	126	128	131	133	134	135
1 in.	109	119	124	128	130	133	135	136	137
2 in.	112	122	126	130	132	135	137	138	139
3 in.	115	125	129	133	135	138	140	141	142
4 in.	118	128	133	136	138	141	143	144	145
5 in.	122	132	137	140	142	145	147	148	149
6 in.	126	136	141	144	146	149	151	152	153
7 in.	130	140	145	148	150	153	155	156	158
8 in.	134	144	149	152	155	158	160	161	163
9 in.	138	148	153	156	160	163	165	166	168
10 in.	142	152	157	161	165	168	170	171	173
11 in.	147	156	162	166	170	174	176	177	178
6 ft. –0 in.	152	161	167	172	176	180	182	183	184
1 in.	157	166	173	178	182	186	188	190	191
2 in.	162	171	179	184	189	193	195	197	198
3 in.	167	176	184	190	195	200	202	204	205
4 in.	172	181	189	196	201	206	209	211	212

HEIGHTS AND WEIGHTS FOR WOMEN AT DIFFERENT AGES

(Based on 136,504 accepted applicants for life insurance)

Height	15 Yr.	20 Yr.	25 Yr.	30 Yr.	35 Yr.	40 Yr.	45 Yr.	50 Yr.	55 Yr.
4 ft. –8 in.	101	106	109	112	115	119	122	125	125
9 in.	103	108	111	114	117	121	124	127	127
10 in.	105	110	113	116	119	123	126	129	129
11 in.	106	112	115	118	121	125	128	131	131
5 ft. –0 in.	107	114	117	120	123	127	130	133	133
1 in.	109	116	119	122	125	129	132	135	135
2 in.	112	119	121	124	127	132	135	138	138
3 in.	115	122	124	127	130	135	138	141	141
4 in.	118	125	128	131	134	138	141	144	144
5 in.	122	128	131	134	138	142	145	148	148
6 in.	126	132	135	138	142	146	149	152	153
7 in.	130	136	139	142	146	150	153	156	158
8 in.	134	140	143	146	150	154	157	161	163
9 in.	138	143	147	150	154	158	161	165	167
10 in.	142	147	151	154	157	161	164	169	171
11 in.	147	151	154	157	160	164	168	173	174
6 ft. –0 in.	152	156	158	161	163	167	171	176	177

While children suffering from malnutrition are usually underweight, occasionally one finds a child who is really undernourished but who appears plump and is of average or even more than average weight for height. In such cases, providing the cause is one of faulty diet and the condition not due to diseased tonsils, etc., it may be that the diet while well-balanced is somewhat deficient as a whole and although the increase in width has kept pace with the increase in height, growth has not been normal when compared with age. In other cases of this type, one finds the diet adequate as regards fuel value but more or less deficient in some of the other requisites, such as protein, mineral constituents, vitamins.

AVERAGE HEIGHTS AND WEIGHTS (WITHOUT CLOTHES) OF CHILDREN BETWEEN ONE AND FOUR YEARS OF AGE

(See Article by F. S. Crum in Quarterly Publication of the American Statistical Association, Boston, September, 1916)

5602 Boys		Age, months	4821 Girls	
Height, inches	Weight, pounds		Height, inches	Weight, pounds
26.5	18.0	6	25.9	16.8
27.3	19.1	7	26.5	17.4
27.6	19.8	8	27.0	18.3
28.1	20.4	9	27.6	19.1
28.5	20.9	10	27.9	19.5
29.0	21.4	11	28.4	20.1
29.4	21.9	12	28.9	20.8
30.8	23.6	15	30.1	21.9
31.8	24.6	18	31.1	23.4
32.9	25.8	21	32.3	24.8
33.8	27.1	24	33.4	26.4
34.8	29.0	27	33.9	27.3
35.4	29.5	30	34.9	28.3
36.1	30.6	33	35.6	29.1
37.1	32.3	36	36.8	30.5
37.9	33.1	39	37.3	31.6
38.6	33.8	42	38.0	32.5
39.0	34.5	45	38.5	33.5
39.5	35.9	48	39.0	33.8

The following tables, giving the average height in inches and weight in pounds of boys and girls, are the ones used by many Child Welfare Associations. They were compiled by Dr. T. D. Wood.

AVERAGE HEIGHT AND WEIGHT OF BOYS AT DIFFERENT AGES

Height Inches	5 Yr.	6 Yr.	7 Yr.	8 Yr.	9 Yr.	10 Yr.	11 Yr.	12 Yr.	13 Yr.	14 Yr.	15 Yr.	16 Yr.	17 Yr.	18 Yr.	19 Yr.	20 Yr.
39	35															
40	38	36														
41	39	39														
42	41	41														
43	42	42	42													
44	46	44	43													
45		46	46	45												
46		48	48	48												
47			49	50	50											
48			54	53	53	53										
49				54	55	55										
50				57	58	58										
51				59	60	60	61									
52					62	62	61	63								
53					62	65	65	67	67	67						
54					65	68	68	70	71	71						
55						69	71	75	75	76						
56						71	77	76	78	79	79					
57							77	79	80	82	82					
58							78	84	85	86	87					
59								84	86	90	91					
60								85	91	94	95	90				
61									98	97	99	96				
62									99	103	106	104	105			
63									100	107	112	112	110	118		
64										114	118	120	117	120	120	
65										122	119	122	122	120	126	125
66											121	125	125	126	129	130
67											128	129	128	131	134	132
68											133	133	130	136	136	136
69											134	136	139	139	139	139
70											136	140	143	143	144	145

The importance of protein in the diet has been discussed elsewhere, also the fact that all proteins are not of equal value as builders. Experience indicates that this constituent is frequently deficient in amount and of poor quality for growth. A fairly safe rule is to provide, for growing children, from three-quarters to one gram of protein for every pound of body weight (without clothes) and for adults one-half gram per pound. It is sometimes more convenient to calculate the protein in terms of calories, rather than as grams, and as one gram of protein will yield, when burned in the body, 4 Calories, the requirement per pound of body weight (without clothes) may be stated thus — 3 to 4 Calories from protein for children and 2 Calories from protein for adults. While the child's protein requirement in proportion to body weight is greater than that of adults, so is its fuel requirement, and therefore a convenient method of stating the protein requirement is that on an average the protein must supply from 10 to 15 Calories out of every hundred or in other words from 10 to 15 per cent of the total calories should come from protein. The following chapters will give tables from which the protein content of a diet may be easily estimated. In malnutrition cases the quality of the protein is usually faulty and this may be corrected by including in the diet at least sixteen to twenty fluid ounces of good milk.

Another general dietary fault is deficiency of mineral constituents — especially of calcium, of phosphorus, and of iron.

AVERAGE HEIGHT AND WEIGHT OF GIRLS AT DIFFERENT AGES

Height Inches	5 Yr.	6 Yr.	7 Yr.	8 Yr.	9 Yr.	10 Yr.	11 Yr.	12 Yr.	13 Yr.	14 Yr.	15 Yr.	16 Yr.	17 Yr.	18 Yr.	19 Yr.	20 Yr.
39	34															
40	37	35														
41	38	37														
42	41	39	39													
43	41	41	42													
44	45	43	44	42												
45		45	45	45												
46		48	47	47												
47			50	49	49											
48				51	51											
49				53	53	54										
50				56	56	57										
51					59	58	60									
52					63	62	62	63								
53						64	63	66	65							
54						69	68	69	68							
55							70	71	73							
56							75	75	76	78						
57								78	80	83						
58								83	86	88	89					
59								88	89	93	97	100				
60								94	94	96	100	104	109	103	99	99
61									99	100	102	109	109	106	105	111
62									104	104	106	111	110	107	111	114
63										107	109	116	110	112	113	114
64										112	118	116	117	114	119	115
65										114	118	121	125	120	123	125

One cannot imagine a diet entirely devoid of calcium, but investigations show that this constituent is very frequently inadequate in amount. If the quantity of milk, suggested to insure a suitable quality of protein, is provided, it will at the same time supply the necessary calcium and also a large part of the required phosphorus. We are told of poor children not being allowed milk on account of the expense — a most erroneous idea considering its value in the diet — and we also hear of children in homes of comparative wealth being allowed to eat what they please and refusing to take milk (our chief source of calcium) in any form. It is not surprising if the bones and teeth of such children are found to be greatly below par. The parents of these boys and girls would be aghast if they were charged with cruelty to their children, but is it not one of the worst forms of cruelty to condemn a child to suffer probably throughout life?

And this is the inevitable result of continued faulty feeding. The children are innocent and not to be held responsible because they cannot be expected to know what they need and a child's appetite is easily perverted. Unfortunately many mothers are also ignorant but they should take advantage of the opportunities offered to increase their knowledge regarding diet and health. Imagine a mother giving her three months old infant, between feedings, water sweetened with saccharine — a substance of absolutely no food value but injurious to the child in two ways, as it tends to upset the child's digestion and perverts its natural appetite. Is it any wonder that many small children refuse the mildly flavored milk and other foods that should form their dietary? It would appear that when the natural appetite is not perverted, animals, if given a choice, seem to select the food supplying their requirement. Osborne and Mendel

experimented with a few rats and found when they were offered a good food and an inferior one they chose sufficient of the former to facilitate growth. The writer, when at a summer resort, was interested in the behavior of about twenty chickens that were fed grain but had no access to grass or other greens. To see what would happen, juicy green grass and tender dandelion leaves were picked and offered to the chickens and they almost fought one another to get the greens and would always leave their corn and other grain for a mess of dandelion leaves. The rate of growth seemed to increase after the daily ration of greens was offered. Evidently civilized man's appetite has been perverted.

The minimum daily requirement of calcium, phosphorus and iron has been estimated from feeding experiments with men and women. No doubt various factors influence the amount needed by different individuals but a "safe" minimum may be estimated by allowing a "margin of safety" above the average minimum as found by experiment. While some foods are entirely lacking in these mineral constituents, others are a fair or even a very rich source of supply. For convenience in estimating the value of a food as a source of mineral matter and also for ease in reckoning the mineral content of a diet, the requirement may be stated as so much per 100 Calories. Using this method, the calcium requirement has been calculated as 0.023 grams per 100 Calories, the phosphorus 0.044 grams per 100 Calories and the iron 0.5 milligrams per 100 Calories.

The iron content of the diet of an undernourished child is generally very low and the providing of this constituent needs especially careful consideration. There is no one food that will easily supply the requisite iron as milk supplies the calcium. The use of so many prepared foods and the refining of our food products tend to lower the iron content of many diets. A deficient amount of iron invariably leads to an anemic condition, although anemia is not necessarily the result of a faulty diet. Too little iron means poor blood and a lowered capacity for carrying oxygen which is essential for the combustion or oxidation of the fuel foods; poor blood causes poor digestion; poor digestion in turn further impairs the quality of the blood and so a vicious circle, that is difficult to overcome, is created. Investigations show that iron as found in natural foods is of far greater value as a blood builder than medicinal iron.

An examination of the dietary of malnourished children very generally shows a predominance of what are called "acid-forming" foods. Some of the minerals have acid characteristics while others have an alkaline reaction. In some foods the acid and alkaline elements are balanced and the food as a whole is neutral in reaction, but in most foods there is an excess of either the one or the other. Foods which contain an excess of the acid elements, or in other words those which yield an acid residue or ash, are called "acid-forming", while those yielding an alkaline ash are said to be "base-forming". Cereals, flesh foods, eggs and cheese are acid-forming, while milk, vegetables and fruits, with few exceptions, are base-forming.

Another common fault in the diet of poorly nourished children is its low vitamin content. Although vitamins have not been identified chemically, we do know definitely of the existence, in most natural food products, of certain substances to which the name "vitamins" has been given. As a result of observation of the physiological effects of these substances it has been proved that at least three such factors exist. There has been considerable controversy as to suitable names for these three substances but the tendency at present is to designate them as "vitamin A", "vitamin B" and "vitamin C". Of these three vitamin B is the one to which the name "vitamin" was first given by Casimir Funk. It is known as the antineuritic, antiberiberi or water-soluble vitamin, and recent experiments indicate the possibility that it may include more than one substance. Vitamin A is the one often spoken of as "fat-soluble vitamin" — so called because of its association with fats. It is also known as the "antixerophthalmic vitamin".

Although the discovery of the presence of these two factors is of recent date, it has been common knowledge for many years that certain foods possess antiscorbutic properties. Dr. J. H. Hess, in his "Scurvy, Past and Present", tells how it was known early in the seventeenth century that scurvy might be prevented, on long sea voyages, by the use of lemon juice. This knowledge of antiscorbutic foods has enabled people to successfully combat scurvy for many generations, but it is only very recently that this property of certain foods has been shown to be due to a definite substance to which the name "antiscorbutic vitamin" or "vitamin C" has been given.

We do not yet know the chemical nature of vitamins, nor even exactly the manner in which they exert their influence in the body; however, feeding experiments have demonstrated that for optimum well-being an adequate supply of the three vitamins is essential. At present one cannot state definitely the amounts required, nor the definite amount of foods that will supply the vitamin requirement, but sufficient has been learned to enable us to intelligently use foodstuffs as sources of vitamins A, B and C. The vitamin content of foods will be discussed briefly in the chapters that follow and as further experimental work is conducted we may hope for more accurate knowledge from the quantitative standpoint.

It may be of interest to review in a general way our present knowledge of some of the properties of the vitamins and their value in the diet. Vitamin A was originally discovered in butter fat and egg yolk fat and was extracted along with the fat by fat-solvents — hence the name "fat-soluble vitamin". However, it is now known that this substance is primarily found in certain plant tissues — especially in those containing chlorophyll — and seems to be often associated with yellow pigments; for instance, certain investigators found yellow sweet potatoes and carrots fairly rich sources of this vitamin, while white potatoes and parsnips were found to be very deficient. If an animal eats food rich in vitamin A, it may be stored in its body to a considerable extent and this stored reserve seems to be an important factor in continued well-being and in the ability to resist infections. Indications are that the animal body cannot synthesize vitamin A and that the vitamin content of butter fat depends primarily upon the food of the cow, hence butter may be considered as a secondary source of fat-soluble vitamin or vitamin A, and plant tissues a primary source. As found in plant tissues, vitamin A is not necessarily associated with fats nor is it always extracted by fat-solvents. Investigations indicate that vitamin A, as found in butter fat, is very susceptible to oxidation at high temperatures but in the absence of air is quite stable to heat. It is thought, however, that vitamin A as found in plant tissues is not readily acted upon by oxidation and is not easily destroyed by heat.

Vitamin A is essential to growth and a continued diet poor in this food factor seems to lessen an animal's resistance, or in other words increases its susceptibility to disease. There is some experimental evidence to indicate that a lack of vitamin A not only conduces to the development of an eye disease known as "xerophthalmia", but may be a factor in other diseases such as rickets and renal calculus. It is also thought that predisposition to diseases such as pellagra and tuberculosis may be increased by the lowered resistance. Some investigators have maintained that lack of vitamin A is the primary cause of rickets, others have demonstrated that rickets may be caused by an absolute or relative deficiency of phosphorus or calcium, but that the tendency to rickets may be aggravated by an insufficient amount of vitamin A. While the primary cause of rickets has not yet been definitely established, there is sufficient evidence to show that an adequate supply of vitamin A at least tends to prevent the disease. Investigations also show that it is necessary for the proper calcification of the teeth. Another point that has been established is the very great importance of a liberal supply of this vitamin during pregnancy and lactation.

Vitamin B is readily soluble in water and hence in the preparation of food may easily be lost if the cooking water is thrown away. This vitamin does not seem to be susceptible to oxidation, neither does it seem to be easily affected by heat at ordinary cooking temperatures; however, careful experiments indicate that there may be considerable loss in cooking under pressure and in commercial canning. Vitamin B is less stable in an alkaline than in an acid solution and this fact leads one to question the advisability of adding baking soda in cooking certain vegetables.

Experimental evidence indicates that we are entirely dependent upon our daily supply of this vitamin, for it cannot be stored in the body, and that a deficiency causes lack of appetite followed by cessation of growth in a young animal and with old and young alike a continued deficiency finally leads to beriberi. McCarrison has found that a partial deficiency leads to functional disturbances of the organs of digestion and assimilation, also of the endocrine or ductless glands and malnutrition of the nervous system. He believes that many ill-defined cases of poor health may be traced to a partial deficiency of this vitamin. It is thought that there is a quantitative relationship between the amount of carbohydrate in the diet and the requirement of vitamin B, so a deficiency may be either absolute or relative — an increased amount of starch and sugar in the diet necessitates an increased requirement of vitamin B. (See "Studies in Deficiency Disease", by Robert McCarrison, 1921.)

The antiscorbutic vitamin or vitamin C is, like vitamin B, readily soluble in water but it is not nearly so stable and is much more easily destroyed. Vitamin C is very susceptible to oxidation, also to heat. There has been considerable quantitative work done with regard to the destruction of this vitamin and it has been found that when heated in a water solution the rate of destruction is influenced by various factors, such as time, temperature, reaction of solution, etc. Vitamin C is much more stable in an acid medium than in either neutral or alkaline solutions.

Experiments show that the vitamin is less susceptible to heat when in the natural condition — as in the cells of the cabbage leaf — than in the expressed juice. There are often considerable losses of vitamin C as a result of storing, drying or aging and these losses are thought to be due partly to oxidation and partly to heating — the time, temperature, etc., being factors influencing the rate and amount of loss.

A lack of vitamin C leads to scurvy, while a partial deficiency may lead to a less well-defined condition called by Hess "latent" or "sub-acute" scurvy. It has also been shown by various investigators that a partial deficiency may have a more or less serious effect on developing teeth. In fact it has been suggested that such a lack may be an important factor in tooth decay and pyorrhea. It is very evident that an adequate supply of all three vitamins is essential in order to attain optimum well-being and that a more or less serious condition results from the partial lack of any one of the three.

In the process of living, waste products are being formed continually in the body and one cannot have good health unless this waste material is promptly eliminated. A dietary providing an excess of base-forming foods helps in the elimination of waste products from the blood and sufficient water also aids in getting rid of them. The elimination of waste material from the intestines is greatly helped by including a reasonable amount of so-called "roughage" in the diet. The cellulose of fruits and vegetables is the main source of roughage. It aids the peristalsis of the digestive tract and thus tends to help digestion as well as to prevent undue retention of waste material. Constipation and "best" health can never go hand in hand and every effort should be made to provide a normal diet that will be anticonstipating rather than to resort to drugs. One almost invariably finds a constipated condition in cases of malnutrition.

As previously stated the food must supply every requisite for body building and body maintenance, and not only must the essential materials be provided, but to

be of any value they must be furnished in a form in which they can be digested. It is only the food that is digested and absorbed that is available to supply the needs of the body.

Undoubtedly physical development depends to a great extent upon an adequate food supply, in fact it seems evident that of all factors food is the most important and hence the food supply is a vital element in national progress.

Food a factor in mental development

It is perhaps more difficult to prove conclusively that food does affect mental development than to show definitely its effect on physical growth. Generally speaking one would expect the physical to affect the mental and observation has indicated that, other things being equal, the better nourished the child, the greater the mental ability.

Recently the writer has had the opportunity of observing the results of an improved diet upon the mentality of a group of nine children. The children selected for the test ranged between 8 and 14 years of age. They were chosen by the teacher and school nurse and were considered below par both mentally and physically. The Terman revision of the Binet-Simon intelligence tests was used as a gauge of mental ability and was given at the beginning and end of the period of improved feeding.

Shortly after the diet was improved, all but one of the nine children showed signs of greater mental alertness. One boy, while he improved physically, showed no sign of mental improvement, and, although his teacher thought he seemed more interested in his school work, his intelligence quotient remained stationary and it was thought that his mental condition was hereditary. The other eight showed a more or less marked improvement as indicated by the table which appears on the next page.

A nation's progress is vitally affected by the mentality of its citizens and, providing there is capacity for mental growth, food is undoubtedly an important factor in mental development.

Food a factor in moral development

It is difficult to measure moral development and hence not easy to produce convincing evidence of the various influences that affect it, but that one of these is food there can be little doubt. The story of life in ancient Egypt furnishes us with an example. We are told that once a month the artisan was paid his wages in grain and a few other provisions, and when the food supply became low, as usually happened toward the end of the month, riots were very common and the half-starved men difficult to control. At the present day somewhat similar accounts appear in connection with detention institutions. It has been said that where the meals are satisfactory, discipline is comparatively easy, but very difficult where it is not. Some have ventured the opinion that inadequate food is probably one factor responsible for the need of detention institutions. Further it has been frequently claimed that monotonous and inadequate food on the one hand, and too highly seasoned food on the other, have had much to do with creating and increasing an appetite for alcohol.

In conclusion, it seems probable, in fact certain, that the physical condition to some extent influences the mental and moral, and hence food which is fundamental to physical well-being is of vital importance to the progress of the race. Further, we must recognize the fact that adequate food means that each essential constituent must be provided in suitable amount and in digestible form; that a partial deficiency of even any one essential may be a limiting factor inhibiting normal all-round development. As Gowland Hopkins has said recently, "What we have actually to recognize is that each of several factors may become that which limits efficiency, and that no one of these is in any strict sense more important than any other. Normal nutrition calls for a certain minimum of each one and every one. If a diet is harmoniously balanced in a chemical sense, then indeed energy does become the sole limiting factor. Nutrition then fails, of course, only when too

RESULTS OF IMPROVED FEEDING UPON THE MENTALITY OF CHILDREN AS SHOWN BY THE TERMAN REVISION OF THE BINET-SIMON INTELLIGENCE TESTS

Subject	Before Feeding					After Feeding				
	Date	Chronological Age	Mental Age	Intelligence Quotient	Remarks	Date	Chronological Age	Mental Age	Intelligence Quotient	Remarks
		Yr. Mo.	Yr. Mo.				Yr. Mo.	Yr. Mo.		
E. G.	Nov. 2	8 0	7 2	90	"Normal" but apparently "Dull"	Jan. 24	8 3	8 2	99	"Normal" but great improvement noted during tests
W. H.	Nov. 18	12 7	8 11	71	"Border-line Deficiency"	Jan. 23	12 9	8 11	71	Same
R. M.	Nov. 17	9 5	7 10	83	"Dull," easily fatigued during tests	Mar. 16	9 9	9 5	96	"Normal"
M. W.	Nov. 23	11 7	8 4	71	"Border-line Deficiency"	Jan. 25	11 9	9 4	78	In same class but quite an improvement
M. L.	Feb. 9	8 11	7 10	89	"Dull" but on "Border-line of Normal"	Apr. 13	9 1	8 4	92	"Normal" with marked improvement noted during tests
L. H.	Jan. 13	13 5	9 8	72	"Border-line Deficiency"	Apr. 10	13 8	10 5	76	About same slight improvement noted
E. R.	Jan. 30	13 2	9 7	73	"Border-line Deficiency"	Apr. 11	13 4	10 8	80	"Dull"
W. T.	Feb. 2	12 4	11 4	92	"Normal"	Apr. 12	12 6	13 0	104	"Normal" but a marked improvement
J. T.	Feb. 4	12 9	8 8	68	"Feeble-minded"	May 6	13	10 9	82	"Dull"—a marked improvement

Intelligence Quotient	*Classification*
90–110	Normal or average intelligence
80–89	Dull
70–79	Border-line Deficiency
Below 70	Feeble-minded

little of the diet is eaten to yield the essential minimum of energy. But the supply of fat may become the limiting factor, and no less that of carbohydrate. Or, again, when the supply of energy consumed is ample, with fat and carbohydrate duly adjusted, the circumstance that a single essential amino acid in one case, or a vitamin in another, is present in amount below the necessary minimum converts each of these in turn into the factor which limits utilization. Small as the necessary minimum in either case may be, unless it is reached the proper use of the rest of the diet is reduced to a degree which is proportional to the deficiency. If the deficiency be complete, normal utilization is altogether impossible."

SHADOWS IN THE HEAVENS

The Conditions of Eclipses of the Sun and Moon, and the Strategy of Observation

DOES GRAVITATION BEND LIGHT RAYS?

AN eclipse of the moon, and still more an eclipse of the sun, must always be a strange and awe-inspiring spectacle. The word "eclipse", meaning in Greek "fainting" or "failing", shows what the ancients felt as they watched the darkening of the heavenly lights; they saw them languish and swoon under some dreadfully ominous visitation. Eclipses, like comets, were taken to be portents of war, pestilence, the death of princes, or even of the end of the world; and to this day certain more primitive peoples come to the aid of the sun or moon with various rites and clamorous supplications.

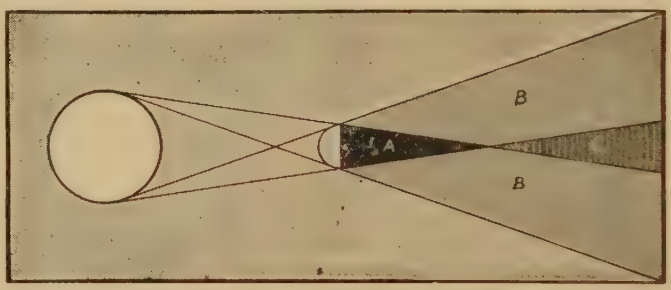
Eclipses are caused by the shadows of the earth and of the moon. The earth and moon being opaque bodies, each of them always has a shadow extending outward into space away from the sun; and because both earth and moon are smaller than the sun, the shadow of each of them is conical, and diminishes in diameter as it proceeds outward into space, until it comes to a point. As the moon travels round the earth once in every month, it sometimes throws its shadow on a portion of the earth's surface, and sometimes its own globe enters into the earth's shadow. The former case, causing a solar eclipse, can only take place at new moon; the latter, causing a lunar eclipse, can only take place at full moon. There would, therefore, be an eclipse of the sun at every new moon, and an eclipse of the moon at every full moon, if the moon's orbit round the earth were quite in the same plane as the earth's orbit round the sun.

The moon's orbit, however, is not in the same plane as the earth's orbit, but is slightly inclined to it. The moon passes through the plane of the earth's orbit twice every month, being for half the month below that plane, and for half the month above it. Usually, therefore, the moon's shadow at new moon passes above or below the globe of the earth, and thus the moon fails to eclipse the sun. Usually, also, at full moon, the moon passes above or below the earth's shadow, and so fails to be itself eclipsed. But from time to time the moon is at full moon or at new moon at the moment when it is at one of the points where its orbit crosses the plane of the earth's orbit; and when that happens, there is a lunar eclipse at full moon or a solar eclipse at new moon. The plane of the earth's orbit round the sun, or, more precisely, the great circle in which this plane cuts the celestial sphere, is called the "ecliptic", and the points in the orbit of the moon where it crosses the plane of the ecliptic are called the "nodes" of the moon's orbit. Eclipses, whether of the sun or of the moon, take place when the moon is at or near the nodes of its orbit.

Let us now consider the different parts of the shadow which is thrown by the earth or the moon. They may be illustrated by a diagram which represents an opaque and non-luminous globe, illuminated by a larger and luminous globe. The diagram found on the next page does not represent the relative sizes or distances of the sun and earth, or of the sun and

moon, but it shows well enough the various regions of complete and partial shadow which are actually projected into space by the earth and the moon. In the first place, there is the central region of complete shadow, the umbra, marked *A*. An object situated within any part of this cone receives no light from any part of the luminous body; and an observer within this cone cannot, therefore, see the source of light at all.

Secondly, surrounding the cone of complete shadow, there is a region of partial shadow, marked *B*. This is known as the penumbra. Any object within it receives light from a portion of the luminous body; and an observer within it can see a portion of the source of light. Thirdly, the lines, or rather the surface, bounding the conical region of complete shadow, if extended outward beyond the point of the cone, form an inverted cone, marked *C*, which is called the negative shadow. Any object within the negative shadow receives light from an external ring of the luminous globe; and an observer in any part of the negative shadow will see the source of light as a luminous ring round the opaque body which is interposed.



THE DEGREES OF DARKNESS IN ECLIPSES
For a full explanation see text.

It is not difficult to calculate the length of the shadows of the earth and of the moon. It is evident from the diagram that the length of the cone of complete shadow depends upon three factors — the diameter of the source of light, the diameter of the opaque body, and the distance between these two bodies. These three factors are known with considerable accuracy, both in the case of the earth and in that of the moon. But while the diameters of the sun, earth and moon are constant factors, the distance between sun and earth and between sun and moon are variable factors. Consequently, the shadow of the earth and the shadow of the moon vary in length. The length of the earth's shadow, at its longest, is about 871,000 miles; at its shortest, about 843,000 miles; and at its mean, about 857,000 miles. The length of the moon's shadow is about 236,000 miles at longest, about 228,000 miles at shortest, and its mean is about 232,000 miles.

The length of the earth's shadow being about 857,000 miles, and the average distance of the moon from the earth being only about 239,000 miles, it is obvious that when the moon plunges into the shadow of the earth it is much nearer to the base than to the tip of the conical shadow. The diameter of the cone, where the moon passes through it, varies from about twice the diameter of the moon to about three times that diameter. If the path of the moon happens to go right through the center of the shadow, the moon may remain totally eclipsed for about two hours. To this time must be added another hour from the first contact of the moon's disc with the shadow until the moment of total eclipse, and yet another hour during the emergence of the moon from the shadow, so that a lunar eclipse may last, from beginning to end, as long as four hours.

On the other hand, the total phase of the moon's eclipse may last only a few minutes if the path of the moon takes it near the edge of the shadow. If the moon's path is such that only a portion of its disc, and not the whole, enters into the conical shadow, the eclipse is partial and not total. Sometimes its path, escaping the cone of complete shadow, takes the moon through the penumbra of the earth, but under these circumstances so much light is still received from a portion of the sun's disc that there is no marked obscuration of the moon unless it passes very close to the true shadow.

The moon is usually not altogether lost to sight even in the midst of a total eclipse, but shines with a strange, lurid, copper-colored glow. Although the earth's globe, so much larger than the moon, is interposed directly between it and the sun, yet sunlight reaches the moon's surface with sufficient illumination to show up the main lunar features. This is sunlight which has been deflected by the earth's atmosphere. When we witness from the earth a total eclipse of the moon, observers on the moon would see a total eclipse of the sun, but they would see the great ball of the earth surrounded all round its edge by a glowing ring of sunlit atmosphere; and the rays which would thus reach their eyes constitute the light that illumines the moon during total eclipse. The terrestrial atmosphere acts as a lens, bending some of the sunlight which passes through it into the shadow of the earth. If, however, the earth's atmosphere be heavily laden with clouds, and is consequently comparatively opaque, it fails to deflect sunlight into the earth's shadow; and under those conditions the moon's surface may be so obscured as to be altogether invisible. The lurid, ruddy color during an eclipse is due to the quality of the atmosphere to which we owe the gorgeous tints of sunset. The light which thus passes from the sun to the eclipsed moon has obviously had to traverse more than twice the distance through the atmosphere which the rays of the setting sun have to traverse before they reach our eyes; and the tinting effect of the atmosphere, with which we are familiar in sunsets, is more than doubled.

Eclipses of the moon are not quite so frequent as eclipses of the sun. There are years within which there is no eclipse of the moon; and in general it may be said that there cannot be more than two lunar eclipses in any one year. If, however, there is an eclipse of the moon on one of the first days of the year, it is possible that there may be a third eclipse in December. The statement that eclipses of the sun are somewhat more frequent than eclipses of the moon seems to be contrary to our experience, for everyone must have noticed that in the country where he lives eclipses of the moon are considerably more frequent than eclipses of the sun. These two facts are not really in contradiction with one another. The moon's shadow, as it reaches the earth, covers only a very small space, whereas the earth's shadow, as it reaches the moon, is more than twice the moon's diameter. Every eclipse of the moon is therefore visible to the inhabitants of more than one-half the earth's surface, but the regions from which any particular eclipse of the sun can be seen lie in a very narrow track across the globe.

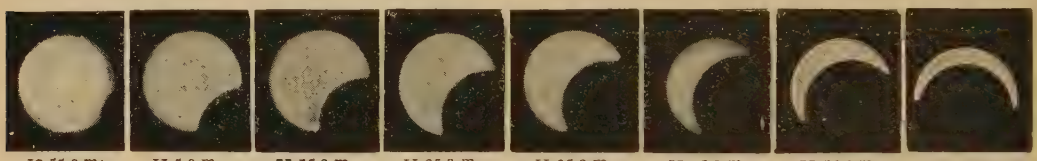
A SOLAR ECLIPSE VIEWED FROM SPACE

Astronomers have to undertake expeditions to remote corners of the world to study eclipses of the sun, but eclipses of the moon can be seen at home. Yet, from the astronomical point of view, eclipses of the sun are incomparably more important, as well as more frequent. There are at least two solar eclipses every year, and there may be as many as five.

Inasmuch as eclipses both of the sun and of the moon depend upon the regular movements of these bodies, their occurrence, both in the future and in the past, can be calculated with great exactness. Thus we know from published tables, of which the best known are Oppolzer's, that within the next ten years total eclipses

of the sun will take place on the following dates: January 24, 1925; January 14, 1926; June 29, 1927; May 19, 1928; May 9, 1929; October 21, 1930; August 31, 1932; and February 14, 1934. Of these eclipses two will be visible in part of the United States, those, namely, occurring in 1925 and 1932. The list of future eclipses might be indefinitely extended for thousands of years to come.

The power, within certain limits, to foretell the occurrence of an eclipse appeared very early in the history of scientific knowledge. The Chaldæans were able and patient students of the heavens: we have, for instance, records of a total eclipse of the sun observed in Babylon as early as 1069 B.C.; and many centuries before our era every considerable city in the region of the Euphrates and Tigris had its observatory and official astronomers. Thence astronomical knowledge passed to Greece, where Thales of Miletus, the earliest of Greek philosophers, made a vast reputation by predicting an eclipse, which duly took place, on May 28, 585 B.C.



PARTIAL ECLIPSE OF THE SUN. — A SERIES OF PHOTOGRAPHS

This early astronomical feat is, after all, not so surprising as it may appear, for patient observers who were careful to keep records of celestial events must soon have become aware of the periodic recurrence of eclipses of the sun and of the moon. Such is the regularity of the movements of the heavenly bodies that whatever eclipses take place in any particular year will be repeated after an interval of eighteen years eleven days and about eight hours, so that eclipses come round again at the right time with the precision of the hands of a clock. This period of recurrence is still known as the "saros", a name meaning "repetition", applied to it by the ancient Chaldæans. In each saros there are about seventy eclipses, including about forty eclipses of the sun and about thirty of the moon.

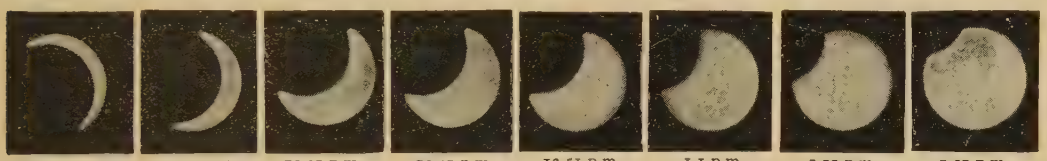
It must be added, however, that although each eclipse of the sun or moon recurs after this period of eighteen years and eleven and one-third days, every such eclipse only has a certain limited life, the life of a solar eclipse being considerably longer than that of a lunar eclipse. Thus, an eclipse of the sun begins as a partial eclipse, in which the moon only slightly encroaches on the sun's disc. At the recurrence of the same event after the period of the saros, the moon obscures a larger area of the sun. Next time, the eclipse, though still partial, is again greater in extent; and this extension of the eclipse is repeated after every saros. These partial eclipses are followed ultimately by a series of annular and total eclipses, in which, from some place on the earth's surface, the moon is seen to pass across the center of the sun's disc, either nearly covering it, as in an annular eclipse, or obscuring it altogether, as in a total eclipse. Finally, the eclipse dies out, as it arose, by a series of ever-diminishing partial eclipses. In this way the same solar eclipse returns at the interval of the saros, at least sixty-eight times and it may be as often as seventy-five times, the whole process, from its first to its last appearance, covering nearly thirteen centuries. Any given eclipse of the moon increases and declines in the same way, but has a shorter life, recurring only forty-eight or forty-nine times, at intervals of eighteen years and one-third days; so that the whole life of a lunar eclipse, from its first to its last appearance, extends to less than nine centuries.

Eclipses of the sun are of three kinds — partial, annular and total. An observer situated within the penumbra of the moon, marked *B* on the diagram on page 2584, sees a partial eclipse; one within the negative shadow, *C*, an annular eclipse; and one within the true shadow, *A*, a total eclipse.

We have seen that the mean length of the moon's shadow is about 232,000 miles, and its greatest length is about 236,000 miles. The mean distance of the earth from the moon is, however, a little over 238,800 miles, so that in general the moon's conical shadow is not long enough to reach the earth. At times, however, the moon is within less than 218,000 miles of the earth's surface, and the true shadow may then completely hide from the sun's rays a small area of the earth's surface, causing at that point a total eclipse of the sun over an area which cannot exceed 167 miles in diameter. At other times the moon may be nearly 249,000 miles away from the earth's surface; and if it is then interposed between the sun and the earth its negative shadow will partially obscure a small area of the earth's surface, causing at that point an annular eclipse of the sun. Around the area on the earth's surface where there is total eclipse or annular eclipse of the sun, there is always a very much larger area where there is partial eclipse. This area of partial eclipse, caused by the penumbra of the moon, always extends for about two thousand miles over the earth's surface on each side of the path which is followed by the area of total eclipse: sometimes the area of partial eclipse extends as far as three thousand miles from the path of totality.

The path over the earth's surface, which the area of total eclipse will traverse at any given eclipse of the sun, is carefully computed and mapped beforehand, so that astronomers may take up advantageous positions for observing the eclipse. The moon's shadow passes along this track at a great speed, considerably exceeding a thousand miles an hour; and the longest period for which totality can last at any one point, under the most favorable conditions, is just short of eight minutes.

The approach of a total eclipse of the sun is always described as impressive and even alarming. The clouds darken, the air becomes chill, and a murky gloom pervades the sky. Birds fly to shelter, and other animals show signs of alarm. The temperature falls and darkness rapidly increases. Then the black shadow of the moon, like that of a vast thundercloud, advances with fearful rapidity from the western horizon, covers the land and enfolds the observer. Usually, just before the last rays of the sun are obscured, swiftly moving bands of light and shade, probably due to uneven refraction in the atmosphere, pursue one another over any extended white object. Then the day is like night: but as the eyes become accustomed to the darkness, surrounding objects are seen in strange appearance, without their natural colors. The beholder has the sense of impending calamity. All nature appears to be dead.



12.11 p.m. 12.21 p.m. 12.31 p.m. 12.41 p.m. 12.51 p.m. 1.1 p.m. 1.11 p.m. 1.21 p.m.

TAKEN DURING THE ECLIPSE OF APRIL 17TH, 1912

In the sky, as the eclipse approaches totality, the sun is seen as an excessively narrow crescent of brilliant light, round the eastern edge of the advancing moon. This crescent becomes a mere curved line, and then breaks up into irregular beads of light, known as Bailey's beads. These quickly disappear; totality is complete; and the moment has come for which astronomers have prepared for many months and traveled thousands of miles.

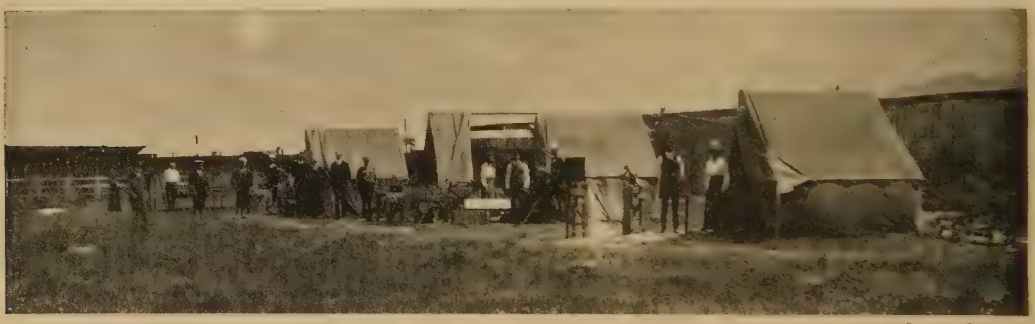
The chromosphere with its prominences, and the corona, which have been already described in Chapter 17, are among the chief objects of study during a total eclipse. But a modern eclipse expedition investigates these structures in several ways, and undertakes many other observations also, and is altogether a very elaborate undertaking, employing many hands and equipped with very elaborate and costly apparatus. Parties of this kind go out from each of the countries which are more

advanced in scientific interests, and often two or three parties from one country; and in the case of the more accessible eclipses these more or less official expeditions are followed by many amateur astronomers. The track of the moon's shadow is dotted in advance with temporary observatories, occupied by eagerly expectant students.

One of the most important points to be determined during a total eclipse of the sun is the precise moment of each of the four contacts. These contacts are: first, when the moon first encroaches on the sun's disc; second, when the last rays of the white light of the photosphere are cut off, and the moon stands out like a round black ball against the corona; third, when the first gleam of the white light of the sun reappears; and fourth, when the moon passes completely off the sun's disc. These times of contact are observed both by the eye with the aid of a telescope, and by means of photography.

The chromosphere and prominences can now be studied, as we have seen, by means of the spectroscope at all times, so that they no longer take up quite so much attention during the brief and valuable moments of eclipse. Observations of the corona, on the other hand, are restricted to the period of totality. Notwithstanding the great advance of photography, ocular impressions of the corona are still indispensable. The observer is blindfolded for ten minutes before the moment of total eclipse, so that his eyes may be in the best condition to perceive the delicate, far-reaching streamers and filaments of light. For the same purpose opaque discs are erected on poles to cut off the brilliant light of the inner corona, so that observers in fixed positions behind them may be sensitive to its tenuous outer structures. Photographs of various lengths of exposure are taken of the corona, and its spectrum is recorded by means of the prismatic camera, in which separate images of the corona are formed, corresponding to each of its constituent elements.

The period of total eclipse is also utilized in searching for possible planets near the sun and within the orbit of Mercury. This search, formerly made by ocular observations with the telescope, is now made more rapidly and completely by means of photography, and the power and efficiency of these methods, thus far applied without results, make the existence of any such planet extremely improbable.



UNITED STATES NAVAL OBSERVATORY ECLIPSE STATION AT BAKER, OREGON, JUNE 8, 1918
Spectrographs, coronal cameras and long-focus camera (lens 7½ inches aperture and 65 feet focal length) with coelostat in background.

The bolometer, an instrument of exquisite delicacy in the measurement of heat radiation, is used to determine the heating effect of the radiation of the corona, with a view to discovering whether the light of the corona is due to reflection of the sun's rays by particles of dust, or to the luminosity of these particles themselves, due to their incandescence from the heat of the sun. For this purpose the heat-rays are spread out, as in the spectroscope, to form what is known as an energy spectrum, and the energy spectrum of the corona is compared with that of the sun itself. If the coronal light is reflected light, the energy spectrum of the corona will be similar to that of the sun, but if it is due to the incandescence of dust particles, the coronal energy spectrum should differ from that of the sun. Bolometric

Photo Yerkes Observatory

PHOTOGRAPH OF THE ECLIPSE OF JUNE 8, 1918 TAKEN DURING TOTALITY

observations of the corona have led to the conclusion that its light is due principally neither to reflection nor to the incandescence of dust particles. The corona radiates too little heat to be quite consistent with either of those theories. It seems to be becoming more probable that the main light of the corona is due to a glow electric discharge, but further observations are necessary to determine the point.

The development of the theory of relativity (explained fully in the biography of its formulator) by Dr. Albert Einstein has added a new interest to solar eclipses and has presented a new problem of great importance to astronomers for solution. This theory is extremely abstruse and is still the subject of discussion in the scientific world. To bring it into contact with reality it was necessary to deduce from it conclusions that could be tested experimentally. Such a method had been pursued with signal success in regard to the theory of gravitation and the wave theory of light, and the verification of such conclusions deduced from Einstein's theory would be the best evidence of its probability, though it does not rise to the dignity of a demonstrative proof of its truth; for such a proof, it

would be necessary to show not only that the facts agree with the given theory but that there is *no other* probable theory sufficient to explain the observed facts. Dr. Einstein himself deduced three physical conclusions which might serve the purpose of testing his theory in the manner indicated above. The first of these has reference to the motion of the perihelion of Mercury. This motion has long been one of the outstanding problems of gravitational astronomy, since observation shows that it is more rapid than can be accounted for by all the *known* gravitational forces exerted on Mercury by the other members of the solar system ; the excess of the observed motion over the calculated motion, as deduced by different scientists, is from 29″ to 42″ per century. Now according to the theory of relativity the sun should produce an acceleration of 43″ per century over and above that required by the Newtonian mechanics; this agrees very closely with the larger of the values indicated above and was accepted by those inclined to favor Einstein's theory as a very striking confirmation. It should, however, be noted that other plausible explanations have been given to account for this anomaly in Mercury's motion as well as other anomalies of lesser magnitude for which Einstein's theory so far offers no satisfactory solution.

Another conclusion deduced by Einstein is that a ray of light should be deflected in passing through a strong gravitational field. It would be impossible to detect such a deflection on the surface of the earth, but the sun's attraction being much greater than that of the earth would have a greater effect, and in 1911 Einstein calculated that a ray of light from a star passing close to the sun's limb should be deflected from its original course by $\frac{7}{8}$ of a second of arc; later on, as a result of further considerations, he announced that the deflection would be double this amount, or 1″.75. Such a phenomenon cannot be detected under ordinary conditions since no stars are visible in the intense glare of the sun in broad daylight. However, during a solar eclipse when the moon blots out the sun's light, stars appear in the darkened heavens in the neighborhood of the sun. The apparent success of the theory of relativity in the case of Mercury's motion suggested to astronomers the desirability of testing Einstein's second deduction at the first favorable opportunity afforded by a total eclipse. An extensive expedition was sent from the Lick Observatory to a station near Kiev, Russia, with special photographic lenses for this purpose on the occasion of the total eclipse of August 21, 1914, but thick clouds intervened and rendered the attempt unsuccessful; the same observatory made a second attempt at Goldendale, Washington, during the eclipse of June 8, 1918, this time with partial success. In 1919 another excellent opportunity offered itself for making these observations during the eclipse of May 29 of that year, and the Royal Astronomical Society sent out two expeditions for this special purpose, one to Sobral in Brazil, under Crommelin and Davidson, and the other to the Island of Principe, in the Gulf of Guinea, under Eddington and Cottingham. At the time of totality the stars in the region of the sun were photographed: the plates were then compared with photographs of the same region taken at night when the sun was in a different portion of the heavens. Careful measurements showed a distinct displacement of the star images in the eclipse photographs. Campbell's results, derived from the Lick plates of 1918, indicated a deflection at the sun's limb of 0″.58. Of the two sets of plates taken with different instruments by the British expedition at Sobral, one indicated a deflection of 1″.98, while the other set gave a value of about 0″.99.

The plates taken at Principe where conditions were less favorable gave a deflection of 1″.61. These values indicate a distinct and hitherto undetected deflection of a ray of light in passing near the sun's limb and hence constitute a discovery of fundamental importance. The numerical results, however, do not agree, either in magnitude or direction, as well as could be desired with Einstein's predicted value,

Campbell's value of 0″.58 is quite small and nearer the amount at first predicted by Einstein and also agreeing with that which would be due to the Newton-Maxwell effect, namely, 0″.87. It should be stated that conditions at the 1918 eclipse were not as favorable as those prevailing during that in May, 1919. The stars in the former were fainter and farther from the sun than those photographed in the latter, and the telescope used was not the best for the work. As for the 1919 eclipse, the star images on the plates giving the lowest deflection of 0″.99 were somewhat out of focus and hence considered untrustworthy; the mean of the two values given by the other plates agrees in magnitude closely with Einstein's predicted value, though the deflection was not directly away from the center of the sun as the theory requires. There is a possibility that refraction in the sun's and the earth's atmospheres have produced some effect, and it is still an open question among scientists whether the results of the 1919 eclipse plates give a real confirmation of the theory. In order to obtain more definite evidence similar photographs were taken with better instrumental equipment during the total eclipse of September 21, 1922, by many different observers. The path of totality passed directly across Australia and over a number of islands adjacent to it; to Wallal, Australia, where the duration of totality was 5 minutes 19 seconds, there were sent five separate expeditions, one from Cambridge, England, one from the University of Toronto, Canada, one from India, one from Perth, West Australia, and the very specially equipped Crocker expedition from the Lick Observatory under the direction of Dr. Campbell. There was also the British expedition, devoted exclusively to testing the Einstein prediction, stationed at Christmas Island, and at this same place was another expedition sent out by Einstein's associates and some amateur astronomers. The preliminary announcements concerning the results of these expeditions indicate once more the presence of a deflection of light agreeing in value fairly well with that predicted by Einstein. The results of the Canadian expedition are announced as "distinctly confirmatory of the theory" though they "can hardly be considered decisive".

The character of the photographs secured by the Lick Observatory expedition was exceptionally good; on each plate there are distinct images of from sixty-two to eighty-five stars. The accurate measurement of the positions of these star images is a task of great delicacy, involving much patient labor extending over many weeks; there were four pairs of plates and it requires fifty hours to make the necessary measurements on each pair, and when all this has been done it still requires many hours of laborious calculations to deduce the amount of deflection of the rays of light indicated by these measurements.

The amount of deflection at the sun's limb as deduced from the measurements made on these plates by Dr. Campbell and Dr. Trumpler is as follows:

	Campbell	Trumpler
First pair of plates	1″.72	1″.88
Second pair of plates	1″.35	1″.62
Third pair of plates	1″.78	1″.91
Fourth pair of plates		1″.76

When all these measurements are properly combined, it is found that the value of the deflection of light by the sun, as observed in the 1922 eclipse, is 1″.72 with a probable error of 0″.11, which is in most remarkable agreement with the deflection of 1″.75 predicted by Einstein. It has not yet been stated whether these deflections as measured on the eclipse plates are all directly along radial lines from the center of the sun, as required by the theory, or whether they include some non-radial components such as were in evidence on the plates taken during the eclipse of 1919.

Whether Einstein's theory as a whole will be ultimately proved true or will be shown to require modification or rejection, it is clear that his investigations have enabled him to lead the astronomical observer to the actual detection and measurement of a previously unknown physical fact which must have tremendous bearings on the future of astronomical and physical sciences.

To obtain satisfactory results in all these different inquiries, and to waste no moment of the precious minutes of the totality, involve extraordinary care and foresight in preparation, organization and drill. Sir Norman Lockyer, a most enthusiastic and capable eclipse observer, did much to bring to perfection the art of conducting an eclipse campaign, and between 1870 and 1905 he was leader of eight eclipse expeditions of the English government. Now no total eclipse, if visible in regions at all accessible, is allowed to pass without the despatch of numerous expeditions manned by astronomers from the principal observatories, and — except where weather conditions have been unfavorable — each of these has further confirmed previous discoveries or raised new questions for future expeditions. In 1905 there were no less than eighty stations observing the eclipse of August 30, which lasted 3½ minutes in Spain, the track running from Labrador to North Africa. There were American, English, Russian and German observers in Egypt, English and French in Algeria and Tunisia, English in Majorca, American and English in Labrador, and nearly all the nations were represented in Spain. The weather conditions were exceptionally good in Algeria and Tunisia, and fair in Egypt but, unfortunately, there were local clouds in Spain and Majorca, and it was cloudy in Labrador so that the advantage of the long line of possible stations was lost. Still interesting results were obtained, notably by the French. Three parties from the Lick Observatory in Egypt, Spain and Labrador, with similar telescopic equipment, conducted an elaborate but unavailing search for intra-Mercurial planets.

Besides the investigations already outlined above, which evidently depend for their success on a clear sky at the time of totality, certain other observations of a geophysical rather than an astronomical nature may be carried out with equal success in cloudy weather as in clear weather. Among such observations are those directed towards detecting and measuring the possible effects of the eclipse upon the earth's magnetic field and its electrical condition. During recent years a number of special expeditions for making such observations have been sent to stations in the region of totality by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington under the able direction of Dr. Louis A. Bauer; in these investigations simultaneous observations are made at the selected stations as well as at all or most of the fixed magnetic observatories of the world so that a minute comparison may be made of the magnetic conditions within the region of totality with those observed elsewhere. These observations indicate a distinct though small perturbation of the magnetic elements during the time of eclipse.

Courtesy Canadian Pacific Railway

MILLERS LAKE, REVELSTOKE PARK, B. C.

LIMPID WATERS FROM THE SNOWY HILLS

LAKE IN GLACIER NATIONAL PARK

FACING PAGE 2503

INLAND WATER RESERVES

Past and Present Formation of Lakes and Marshes,
and Their Slow Disappearance from the Earth

FEATURES OF THE WORLD'S GREAT LAKES

LAKES are bodies of water collected in basin-like depressions of the land. They are intimately connected with rivers, and not infrequently occur in a chain along a river's course. The beds of the lakes, however, unlike the beds of rivers, are not made by the erosion of running water; the running water finds the beds ready-made, and tends not to deepen them, but to fill them up with silt. If not made by running water, how then are the lake-beds made? Some are craters of old volcanoes; some represent depressions in old boulder-clay deposit, which is always spread very unevenly; some are local subsidences in the land; some have been scooped out by glaciers; some have been caused by barriers across valleys, but most have probably been formed by land movements resulting in the bending up and down of valleys.

It will be noticed, therefore, that though running water does not actually make lake-beds, yet in the majority of cases, by the forming of valleys, it prepares the way for the making of lakes, much as it prepared the way for the making of the fiords on the west coasts of Norway and Scotland. Some geologists have considered glaciers the chief agents concerned in the making of lake-beds, but it is probable that the action of glaciers in this way is very limited. When we examine the beds of most lakes, we find that they show signs of sub-aërial, not of glacial, action; and again, when we examine the beds of glaciers, we do not find that they are producing depressions suitable for lakes. Glaciers grind and scratch and polish; they do not gouge and scoop; and though it is quite likely that some small lakes and tarns may have had their beds made for them by glaciers, the beds of such great lakes as the Lake of Geneva, Albert Nyanza and Lugano must have been prepared by actual bendings of the earth's crust, or sometimes, perhaps, by elevations and great subsidences.

Since earthquakes lower and elevate the land, they often make hollows that become lakes. In 1819, for instance, the Delta of the Indus was shaken by a great earthquake, and the Runn of Cutch, a tract of land including 2000 square miles, subsided, and became an inland sea. After earthquakes in the Mississippi Valley in 1811–1812, about five thousand square miles in Missouri were lowered and converted into lakes and marshes. After the earthquake in Central Japan in 1891 several lakes appeared.

We have said that barriers across valleys sometimes make part of a valley into a lake-bed. A common cause of such a barrier is a landslide. In 1512 the course of the River Blegno, in Switzerland, was dammed by a landslide and a great lake was formed. The Lakes of Derborence were formed by slides from the Diablerets. In 1181 a landslide formed a lake $6\frac{1}{2}$ miles long on the plain of Oisans, in the Dauphiny Alps. Villages and forests were submerged, and the inhabitants of the district had to give up farming and take to fishing. After thirty-eight years the lake burst its barrier.

Glaciers sometimes dam river-valleys and form lakes. Thus the ice-dam of the great Aletsch Glacier in Switzerland has formed the Märjelen See. Lakes formed in this way are, of course, far from permanent, and may be suddenly emptied by the bursting of the barrier, or lowered by its gradual melting. In 1818 the Dranse Valley was dammed by a glacier and a large lake gathered, but when attempts were made to drain the lake by tunneling the ice, the ice barrier gave way and fifty people were drowned, and five hundred houses and chalets destroyed.

In a few cases the beds of lakes are made by wind. When the surface of the earth consists of shale and is bare of vegetation, the wind gradually scoops out broad, shallow basins, ready to collect rain in the rainy season. Such lake-beds are found on the great plains of the United States. In sandy deserts subject to sudden changes of heat and cold, the wind has still more excavating power, and there are big tracts of the Sahara which have been worn away to below sea level, and may some day become great inland lakes.

In a few cases, also, lakes are formed by banks and bars of sand, thrown up by the currents of the sea along the coast, which eventually cuts off a lagoon from the sea. Though at first containing salt-water, lagoons may eventually contain fresh. An interesting lake is sometimes formed by a loop of a large river when the river changes its course by short-circuiting across the loop. Such loop-lakes are known as "ox-bow lakes", and are very common in the basin of the Amazon and along the course of the Mississippi.

THE MÄRJELEN SEE AND THE ALETSCH GLACIER, SWITZERLAND

The "parallel roads" of Glen Roy, in Scotland, are supposed to represent the successive levels of a lake which was dammed by a glacier, and which lowered its level as the glacier barrier gave way. In other cases not the glacier itself but its terminal moraine forms the dam which converts part of a valley into a lake bed.

The table on the next page, showing the height, area and depth of the largest lakes, is given by Dr. H. R. Mill.

The largest lake in the world is the Caspian Sea; the highest is Askal Chin, in Tibet, which is 16,600 feet above sea-level; the lowest is the Dead Sea, which is 1290 feet below sea-level, and the deepest is Lake Baikal, in Russian Asia, which has a maximum depth of 4800 feet.

THE HEIGHT, DEPTH AND SIZE OF THE SIX LARGEST LAKES IN THE WORLD

Name	Situation	Height Above Sea in Feet	Area in Square Miles	Maximum Depth in Fathoms
Caspian . . .	Eurasia	90	170,000	500
Superior . . .	North America	600	31,200	168
Victoria . . .	Africa	3,300	26,900	—
Aral	Asia	150	26,200	37
Huron . . .	North America	580	23,800	117
Michigan . .	United States	580	22,400	145

Many lakes exhibit abrupt transitory changes in level. These changes of level are known as "seiches", and may be rocking of the whole mass of water of the lake about fixed lines. In Lake George, in New South Wales, seiches of the fol-

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LAKE MCDERMOTT, GLACIER NATIONAL PARK

either local or general. Those of the Lake of Geneva have been studied in great detail by Forel. The water level there rises and falls through a range of several inches with more or less regularity. The motion is an oscillation, an alternate up and down movement that begins suddenly and lasts for some time. During a celebrated seiche in 1600 the water level oscillated through three or four feet. Forel measured these curious changes in level at various points along the shore. He showed from his observations that the seiches consist of a lowing character have been noticed: "On one occasion, when the lake was very quiet, the water suddenly rose one inch and a half, and fell two inches in three-quarters of an hour; next, it rose two inches, and fell three and a half inches in one hour; finally it rose three and three-quarter inches in forty minutes, and so started a series of pulsations which settled down to two-hour intervals and lasted twenty hours." In the Swiss lakes seiches seem more common by night than by day, and in spring and summer than in winter, and

GLACIERS CREEPING DOWN TO THE LAKES

MORAINE LAKE AND TEN PEAKS

Photos Courtesy Canadian Pacific Railway

LAKE LOUISE: THE GREEN MIRROR FOR THE MOUNTAINS AND GLACIERS THAT SURROUND IT

ONE OF THE THREE LAKES IN THE CLOUDS

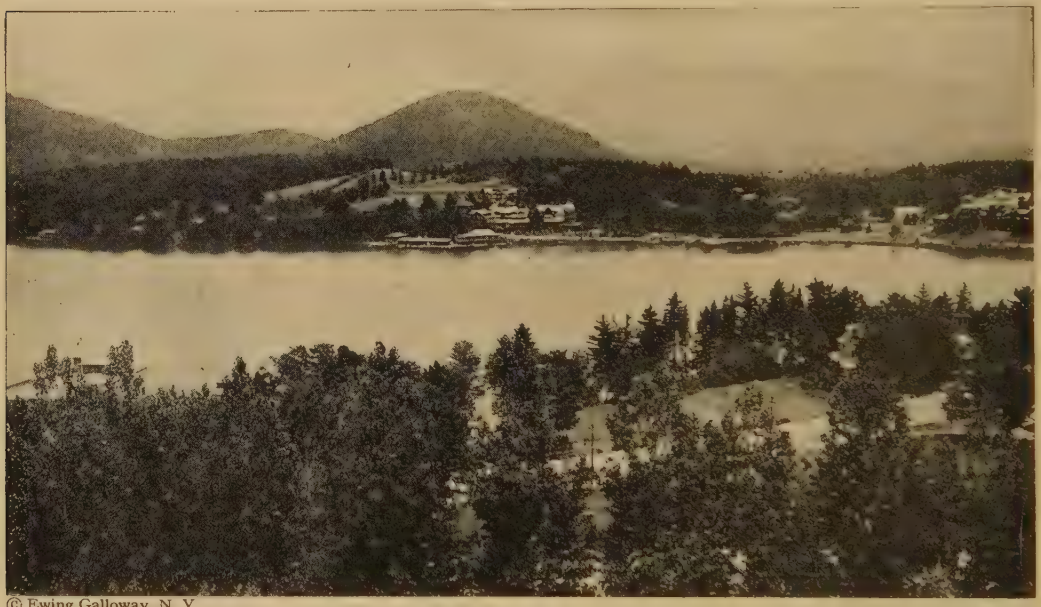
Courtesy Canadian Pacific Railway

MIRROR LAKE IN THE CANADIAN ROCKIES

they frequently occur when the sun "suddenly begins to shine from amid heavy clouds". In Lake George, on the other hand, seiches are frequently associated with thunderstorms.

As for the cause of seiches it seems clear that they must be due to some agency which heaps up the water of the lake at one end and then ceases to act, thus causing oscillations. Such agencies are minute earthquakes, prolonged winds blowing in one direction and then ceasing rather suddenly and also variations in barometric pressure. Similar seiches which occur in the Baltic have been shown to be connected with variations in barometric pressure.

Lakes perform various geological and climatological functions. Like the ocean, they tend to equalize the temperatures of day and night and winter and summer. They filter rivers, precipitating soil and salts; the beautiful blue of so many lakes is a proof of their efficiency as filters. They furnish an abode for special fauna and flora. But perhaps their most important function is to regulate the supply of river-water to the plains, by serving as reservoirs in time of drought, and by retaining excessive rain in rainy seasons. A vast amount of water can pour into a large lake without much raising its general surface, and without much increasing its overflow; and likewise a vast amount of water can be drained from a large lake without much lowering its general surface or diminishing its outflow.



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LAKE PLACID — WITH ITS SUMMER INVASION OF CITY DWELLERS

The temperature of lakes has been carefully investigated, and it has been found that a lake of any depth situated in a temperate country has a mass of cold water which lies along its bottom, and varies little in temperature from month to month. In Loch Lomond, which is about 600 feet deep, the lowest 100 feet of water has a constant temperature of about 42° F., and at the same depth in Seneca Lake, Loch Ness, Loch Oich, Loch Morar, the Lake of Geneva, Lago Maggiore, Lago Lugano and many other lakes the water has about this same temperature.

If a river one-tenth of a mile wide flows into a lake one hundred square miles in area, and then continues its course for ten miles to the sea, a rainfall sufficient to raise the level of its last ten miles by twenty-five feet will be intercepted by the lake, and raise the lake's surface only three inches — a rise that will obviously hardly increase its outflow. Reclus shows this regulating action in the case of the Lake of Geneva: "The gauges used at

Geneva establish the fact that the discharge of the Rhône as it issues from the lake is, at its maximum, 753 cubic yards. Now, as the various affluents of the lake supply more than 1400 cubic yards during their highest floods, it is evident that the Lake of Geneva acts as a complete regulator. It keeps back at least one-half of the inundation water, which it subsequently empties down gradually when its tributaries have retired to their usual level. It is certain that, owing to the regulating action exercised over the discharge of the river, the plains on the bank of the middle course of the Rhône, from Geneva to Lyons, are comparatively protected against floods."

From what we have said of the manner of the making of lakes, it is plain that they belong to comparatively recent geological periods, and it is also plain that they have no elements of permanence. The river does not deepen the lake; it fills it up, and in time abolishes the lake altogether; the lake dammed by the glacier will last only as long as the glacier lasts; the lake scooped out of the sand by the wind will very probably be choked; the aigues-mortes will soon become a marsh.

Lakes may contain either salt or fresh water. Some of the salt lakes, such as the Caspian Sea, originally obtained their salt water from the sea, but others, such as the Dead Sea, have collected the salt for themselves from the land. As a rule, lakes with an outlet contain fresh water; without an outlet, salt; but there are exceptions to this rule.

The largest fresh-water lake in the world is Lake Superior, in North America, which is situated 600 feet above sea-level, and covers an area of 31,200 square miles. Lake Victoria Nyanza, in Africa, comes second, covering an area of 26,900 square miles; and Lake Aral, in Asia, is a good third, with an area only slightly less.

LAKE SUPERIOR — AN INLAND OCEAN'S LIMITLESS HORIZON

Then come Lake Huron and Lake Michigan, respectively 23,800 and 22,400 square miles in area. The five great North American lakes, Superior, Michigan, Huron, Erie and Ontario, together cover an area of 94,650 square miles — an area, that is to say, about the same size as England. Big as the Great Lakes are, there is geological evidence which indicates that a still bigger lake formerly existed — a lake 700 miles long from north to south, and covering an area of about 110,000 square miles. All that is left now of this tremendous lake is a few sheets of water scattered here and there, but there can be no doubt of its former existence, and it

has been named by geologists "Lake Agassiz". At one time, too, both Lake Superior and Lake Huron were larger and deeper than they now are, as is shown by the series of raised shingle beaches that form terraces round their shores.

The salt lakes are particularly interesting. As we have said, there are two classes of salt lakes — salt lakes that derive their salt from the sea, and salt lakes that derive their salt from the rivers that drain into them. Salt lakes of marine origin have been cut off from the parent sea by movements of the earth's crust. They are not very numerous, and they tend to dry up. The largest and most typical is the Caspian Sea. It covers an area of 170,000 square miles, and is therefore almost six times as large as Lake Superior, and almost twice as large as the combined area of the five great North American lakes. It is not only large — it is also deep; its maximum depth is 3000 feet, which is more than three times the depth of Lake Superior.

At one time this great lake was certainly continuous with the Black Sea, for between the two is a chain of salt lakes and marshes. Also, the shells in the Caspian Sea are the same as the shells in the Black Sea, and banks of similar shells stretch between the two seas. It seems probable, too, that at one time a great arm of the Caspian Sea stretched northward over the steppes of southeastern Russia, even as far as the Arctic Sea, since in that direction there are still salty plains and little salt lakes, and since seals which seem a variety of the Arctic species are found in the Caspian Sea. It is strange to think that a lake so far to the south should have seal fisheries, yet the seal fisheries of the Caspian Sea are a big and flourishing industry.

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FULTON CHAIN LAKES, ADIRONDACKS — LOOKING THROUGH THE PINES

At present the surface of the Caspian is about 90 feet below sea-level, the fall being due partly to the movements of the earth's crust and partly to evaporation. The present influx of water to the lake about balances evaporation, but the surface of the Sea of Aral, which once joined the Caspian, is slowly sinking year by year. Were the Caspian to fill up again to sea-level it would flood several hundred thousand square miles of the steppes. Since the covering them and causing a deposit of crystalline salt, which is thus being gradually withdrawn from solution, while evaporation is made good by a continual supply of fresh water".

In the Kara-Baghas itself, which is an offshoot of the Caspian Sea, the waters are much salter, and it has been estimated that every day 350,000 tons of salt are swept into it through the shallow inlet. So salt has the Kara-Baghas become that

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EARLY MORNING MISTS ON BIG MOOSE LAKE

rivers constantly add salt to the Caspian, and since evaporation prevents any increase of water, one would expect the Caspian to be excessively salt, and it is rather surprising to find that on the average it is not so salt as the general ocean, and not even so salt as the Mediterranean. How is this? The reason of this apparent anomaly is that "the shelving shores, and particularly the wide, shallow inlet of Kara-Baghas, act as natural salt-pans, evaporating the thin layer of water the seals have left it, and no vegetation will grow on its banks. Still salter is the arm of the sea called Karasu, where the salinity rises to 5.7 per cent. All round the Caspian Sea there are shallow salt pools and lagoons where salt is concentrated and deposited. "One basin," says Reclus, "still occasionally receives water from the sea, and has deposited on its banks only a very thin layer of salt. A second, likewise full of water, has its bottom

hidden by a thick crust of rose-colored crystals like a pavement of marble. A third exhibits a compactness of salt, in which glitter here and there pools of water situated more than a yard below the level of the sea. Lastly, another has lost by means of evaporation all the water which once filled it, and the strata of salt which carpets its bed are partly covered by sand."

The Dead Sea is a yet more famous lake, famous both because of its salinity and because of the depth of its surface below sea-level. It lies no less than 1290 feet below the level of the Mediterranean, and the predominant salt is not chloride of sodium, or common salt, as in the case of the Caspian Sea, but chloride of magnesium. It has 15.9 per cent of chloride of magnesium, and only 3.6 per cent of sodium chloride. It is probably the large percentage of magnesium chloride that renders the water so destructive to life. Though the Dead Sea must at one time have approached the Red Sea, it is unlikely that it communicated with it, since no trace of iodine is found in the water of the latter, and the foraminifera in the mud of the former do not belong to Red Sea species.

To the west of the Caspian lies Lake

THE DEAD SEA, WHICH IS GRADUALLY INCREASING IN DEPTH

is fed by the Jordan, which enters at its north end and finds no exit. The sea now covers an area of only 460 square miles, but there are layers of marl and beds of salt on the slopes surrounding it, and it is probable that at one time it stretched from the foot of Lebanon to the north of the Red Sea. The lake well deserves the adjective "dead", for no fish live in its waters, and no vegetation grows on its banks. Its salinity is much greater than the salinity of the Caspian Sea, and eight or nine times as great as the salinity of the ocean and its salt content differs greatly from the salt content of the ocean. It contains about 26 per cent of salts, but

Elton, a very saline lake, whose bed consists of layers of salt constantly thickening from year to year. In summer, when evaporation is rapid and the lake diminishes in size, its shores look like immense, glistening snowfields.

In the northwestern part of Utah lies the Great Salt Lake with an area of about 2000 square miles and an average depth of 20 feet. The water is extremely salty, resembling ocean water in composition but nearly six times as dense, containing about 18 per cent of solids. According to Gilbert the lake holds about 400,000,000 tons of sodium chloride, common salt, and 30,000,000 tons of sodium sulphate.

These are the main solids in solution. So dense is the water that it is buoyant to float in, but very difficult to swim in, and it is so acrid that if it gets into one's eye it causes great pain, and inhalation of the spray causes a spasm of coughing.

The only living things in the lake are small worms that burrow in the sand of the shore, and a seaweed of the Nostoc species, and on the shores of the lake only such shrubs are found as can tolerate a saline soil.

At present rainfall and evaporation about balance each other, and the lake preserves a more or less constant level, and neither increases nor diminishes, but, like most other salt lakes, it has known better days. It is, indeed, merely a remnant of a greater lake, an inland sea, as large as Lake Michigan, 20,000 square miles, and over 1500 feet deep, to which the name of Lake Bonneville has been given. This great original lake was a fresh-water lake, and drained into the Pacific by the Snake and Columbia Rivers: its beaches and shore terraces can still be traced along the slope of the surrounding mountains. To the west of this great lake there was a second fresh-water lake almost as large, now called by geologists Lake Lahontan, also draining into the Pacific. As meteorological or geological conditions changed, and these lakes dried up, they became more and more saline, and the deserts of the Great Basin are largely due to the precipitation of salts from the retreating lakes.

The table below, collated from tables given by Geikie and Bonney, shows the comparative saltness of various lakes and seas.

Many rocks have been formed by the precipitation of salts from lake and sea water. The least soluble salts are the first to be precipitated. Evaporation of lake water having a composition resembling sea water would result in a precipitation of gypsum (calcium sulphate), followed by a precipitation of rock salt, and this order is found in saliferous formations. In the case of the Dead Sea, and Lake Elton, and other lakes where the most plentiful salt is the chloride of magnesium, large amounts of chloride of sodium have already been precipitated; and if more chloride of sodium is added to water containing large quantities of chloride of magnesium, the chloride of sodium is precipitated. Hence, when the Jordan brings down additional chloride of sodium to the Dead Sea, the salt is quickly precipitated. The bottom of the Dead Sea, accordingly, consists of common salt and gypsum mixed with mud.

As we have already said, most lakes tend to be filled up. In the course of such filling up they are converted into a marshy condition, and many marshes are simply half-dried lakes. Not infrequently a lake full of water in the rainy season may dry up partially and become a marsh in the dry season. But marshes also originate in other ways. Along the course of rivers subject to overflowing which traverse low-lying land there are always swamps and marshes; and if the river be large it may form correspondingly large swamps and marshes. Even apart from overflowing rivers, any great stretches of level land become marshes if there be sufficient rainfall. The great plains of Brazil crossed by the Paraguay and its tributaries exhibit a

THE SALTNESS OF LAKES, EXPRESSED IN PARTS PER THOUSAND

Deposit	Great Salt Lake	Caspian at Baku	Elton Lake	Dead Sea	English Channel
Chloride of Sodium	118.628	85.267	38.3	36.372	27.059
Chloride of Potassium	.862	Trace	2.3	8.379	.765
Chloride of Magnesium	14.908	03.039	197.5	159.774	3.666
Chloride of Calcium	—	—	—	47.197	—
Sulphate of Magnesium	—	32.493	53.2	—	2.295
Sulphate of Calcium	.858	10.742	—	0.889	1.406
Sulphate of Sodium	9.321	—	—	—	—
Sulphate of Potassium	5.363	—	—	—	—
Carbonate of Calcium	—	00.554	—	—	.033
Bromide of Magnesium	—	—	—	8.157	.029

series of immense marshes. Lake Tchad, in Africa, is so surrounded by bogs that its true dimensions cannot be defined. Where the ground is rich in decayed vegetation the marshes are known as peat-mosses, or bogs, and these are specially interesting as the factories where coal is prepared for future generations. There are hundreds of thousands of acres of bogs in Germany, Sweden, Norway, England, Scotland, Holland, France and Denmark. In Russia it is thought that the bog area exceeds four and a quarter million acres. One-seventh of the whole area of Ireland is covered with peat-bogs; the Bog of Allen alone comprises no less than 238,500 acres with an average depth of 25 feet. In Canada and the United States there are enormous peat formations, careful estimation making the area of swamps, bogs and inundated land in the latter over 60,000,000 acres.

In peat formation vegetable decay, largely due to bacterial action, is stopped by the non-removal of bacterial waste products which make the peat liquids an excellent preservative. This antiseptic quality of peat bogs is well shown in the preservation of bodies of men and animals entombed in them hundreds and probably thousands of years ago. The reclamation of bogs for farming purposes involves draining and plowing up the soil to permit the necessary oxidization processes. Oats are usually the first crop, but, once reclaimed, the soil is very fertile and is especially adapted for the growth of vegetables like celery, onions and the various roots.

Some of the greatest marshes of the world are the salt-water marshes on the shores of the sea. Along the coast of Florida a belt of marsh five to twenty miles wide stretches for many miles. These marshes are often known as mangrove swamps, because they are covered with thick jungles of mangrove trees, which have bird-nests on their branches and crabs and barnacles among their roots. Along the shores of the Gulf of Mexico there are millions of acres of marshes covered not with mangroves but with cypresses, and these, again, are known as "cypress swamps". For centuries it was believed that swamps and marshes gave off poisonous vapors that caused malaria, but it is now known that the malaria is not due to poisonous vapors, but to a tiny animal organism carried by mosquitoes from infected to healthy persons.

A MANGROVE SWAMP IN THE MALAY STATES

A GREAT CONTEMPORARY LEADER

The Work of Dr. Bateson, the Master and Founder of the School of Genetics

THE ANALYSIS OF FORMATIVE UNITS

IN our study of heredity we have found our science so young and so rapidly developing that it was best to deal with it under the names of a few great students; and, having discussed in turn the work of Galton, Weismann, Mendel and De Vries, we come now to the figure of the contemporary leader in this fertile and almost virgin field of science. Professor William Bateson, F.R.S., was the first holder of the chair of biology established at Cambridge University in honor of Darwin. He retired from that chair in order to have more time for research, and became director of the John Innes Horticultural Institution at Merton, in Surrey, and later professor of physiology at the Royal Institution. He died February 8, 1926.

Professor Bateson became the leader of the Mendelian school, the present achievements of which will afterwards, and for long afterwards, concern us. But his preparation for this study began earlier than the present century, and requires our understanding here. We must go back over thirty years, to the publication of his great book, now looked upon as a classic by biologists, which is modestly entitled "Materials for the Study of Variation", and which was published in 1894. The title is modest indeed, but if we think a moment we shall see that it conveys rather more than meets the ear. In fact, it is "a summons and a challenge".

When it appeared, biologists were, for the most part, in a somewhat hypnotic, not to say cataleptic, state, under the influence of Darwin. Herbert Spencer was protesting against the uncritical acceptance of "the all-sufficiency of natural selection", but, as he held no degree and had never passed an examination, of course his observations could be discounted. Hence the title of Dr. Bateson's book was startling, for it seemed to suggest what we now see to be so exceedingly true — that the study of variation had at that time practically not even begun, and that the first necessity was for the collection of exact facts. What this meant and means for Darwinism, or for any other special theory of organic evolution, we can see at once, if we remember that variations are the very material and essential of all evolution, and that, in reality, the study of evolution is the study of variations. Everyone was supposing that evolution had been explained, once and for all. Darwin's remains were in the Abbey, and then there appeared this book, which suggested that, in time, we might be ready to begin at the beginning.

When the natural selection of minute chance variations of living creatures is felt to be an inadequate explanation of the facts of living nature, we ask ourselves — or, rather, Dr. Bateson asked himself — whether there are not other kinds of variation, that do occur not infrequently, and that might far more probably furnish the beginnings of new species. The conclusion to which he came is that there are two distinct kinds of variation, to which he gave the name of continuous and discontinuous variation respectively. The former is universal and illustrated by every living creature, and it is this type of variation in which the theory of Darwin sees the material for natural selection to act upon.

But the conclusion at which Dr. Bateson arrived, as long ago as 1894, was that the very grave difficulties in the way of accepting this theory may be avoided if we turn to the facts of discontinuous variation. In sum, he showed "(1) that differences of the kind which are generally used to distinguish separate species may arise as single variations; (2) that such a form of variation is by no means so uncommon a phenomenon as was formerly supposed; and (3) that variations of this kind may occur in every description of organ and part, in a number of different plants and animals".

We see at once, of course, that there is a substantial identity between the view of Bateson, that organic evolution depends upon discontinuous variations, and the "mutations theory" of De Vries, which we have already studied. And naturally an author who had already come to these conclusions was prepared for the rediscovery of Mendel's paper half a dozen years later. He saw at once that we now required an experimental science, which should begin at the beginning, and try to ascertain the precise facts of heredity and variation, with the aid of the long-lost key which Mendel had provided. Biologists had neglected this essential task. As Dr. Bateson himself says: "Darwin's achievement so far exceeded anything that was thought possible before, that what should have been hailed as a long-expected beginning was taken for the completed work."

Genetics a contribution to the advancement of pure physiological science

Nevertheless, Dr. Bateson founded the science of genetics, primarily "in the hope that it would elucidate the problem of species". But, in the course of the last few years, the possibilities of these experiments have become greatly extended. Here is Dr. Bateson's own statement: "The time has now come when appeals for the vigorous prosecution of this method should rather be based on other grounds. It is as directly contributing to the advancement of pure physiological science that genetics can present the strongest claim. We have an eye always on the evolution problem. We know that the facts we are collecting will help in its solution, but for a period we shall perhaps do well to direct our search more especially to the immediate problems of genetic physiology, the laws of heredity, the nature of variation, the significance of sex, and other manifestations of dimorphism (*i.e.*, 'two-form-ism'), willing to postpone the application of the results to wider problems as a task more suited to a maturer stage. When the magnitude and definiteness of the advances already made in genetics come to be more generally known, it is to be anticipated that workers in various departments of biology will realize that here at last is common ground."

The truth is that experimental breeding is the only way in which we can learn many facts about individuals and their composition and constitution. Genetics was founded, as its name implies, in order to define and study the problems of genesis. But now we discover that in studying these problems we find the clue to all manner of questions which general physiology is interested in. Nothing, for instance, is more interesting for biology in general than the nature of sex.

Genetic experiment began by assuming the fact of sex, of course, and proceeding to observe the consequences of bi-sexual reproduction; but it goes on to see that sex itself is a characteristic which may be studied genetically, just like eye-color. We find that the sex of an individual is one of its features, dependent, like other features, upon certain "factors", or "determinants", in the germ-cells whence it was formed. We learn, too, how strangely this factor of maleness or femaleness affects other characters which are transmitted and represented in the germ-cells beside them, so that if the factor for maleness be present along with the factor which gives rise to what is called the "bleeding disease", the boy will be a "bleeder", but if femaleness and the factor for this disease come together, the girl is *not* a "bleeder", though her sons may be. This is a mere illustration to show how entirely the claim of Dr. Bateson is justified when he suggests that these inquiries are of interest to far more students than those of heredity alone.

Novel and invaluable contributions to the chemistry of physiology

One other illustration of his contention may be referred to. There is a department of science called "physiological chemistry", which studies the chemistry and chemical interactions of the different parts of living bodies. But this science has hitherto been quite unable to throw any light upon the development of the adult body from the germ, though plainly there must be plenty of chemical problems involved therein. Here genetics, with its new method, and its unprecedented angle of attack upon standing physiological problems, makes novel and invaluable contributions. The study of the inheritance of the colors of sweet-peas, for instance, shows how such and such a color may be altered into another by the addition of a special "factor" to the germ-cells. But when we ascertain that the second color is simply an oxidation product of the first, naturally we surmise that the extra factor in the germ-cells which made the difference must be of the nature of an oxidizing ferment. Thus the standing ideas of the architecture of the body and the corresponding architecture of the germ-plasm, so much discussed by Weismann, come to be supplemented by ideas of the chemistry of the body, and the corresponding chemistry of the germ-plasm; and we begin to suspect that these latter ideas are the deeper of the two.

Dr. Bateson's definition of genetics — the physiology of heredity and variation

But this is a case where no exposition by others is required, for we have Dr. Bateson's own words to draw upon; and the best service the writer can perform, for the reader and for genetics, is to present in brief, but with some exact citations, the arguments and the conclusions embodied in Dr. Bateson's inaugural lecture as professor of biology in the University of Cambridge on "The Methods and Scope of Genetics", and we may consider it now in the light of the subsequent knowledge gained in the intervening years. In introducing that lecture Dr. Bateson defines genetics as "the physiology of heredity and variation", and states his belief that "genetic research is still pushing forward in the central undifferentiated trunk of biological science", thanks to "Mendelian discovery leading us into a new world, the very existence of which was unsuspected before".

The two-cell production of all ordinary forms of life, and its consequences

We start from the familiar fact that all the ordinary animals and plants begin their individual lives by the union of two cells, the one male, the other female. "Now, obviously the diversity of form which is characteristic of the animal and plant world must be somehow represented in the gametes, since it is they which bring into each organism all that it contains. . . . The fact that *two* cells are concerned in the production of all the ordinary forms of life was discovered a long while ago, and has been part of the common stock of elementary knowledge of all educated persons for about half a century. The full consequences of this double nature seem nevertheless to have struck nobody before Mendel. . . . We are accustomed to think of a man, a butterfly, or an apple-tree as each *one* thing. In order to understand the significance of Mendelism we must get thoroughly familiar with the fact that they are each *two* things, double throughout every part of their composition. . . . That we are assemblages or medleys of our parental characteristics is obvious. We all know that a man may have his father's hair, his mother's color, his father's voice, his mother's insensibility to music, and so on, but that is not enough.

"Such an analysis is true, inasmuch as the various characters *are* transmitted independently, but it misses the essential point. For in each of these respects the individual is double; and so to get a true picture of the composition of the individual we have to think how *each* of the two original gametes was provided in the matter of height, hair, color, mathematical ability, nail-shape and the other features that go to make the man we know. The contribution of each gamete in each respect has thus to be separately brought to account."

Pure breeding and cross-breeding according to germ-cell ingredients

"If we could make a list of all the ingredients that go to form a man, and could set out how he is constituted in respect to each of them, it would not suffice to give one column of values for these ingredients, but we must rule two columns, one for the ovum and one for the spermatozoön, which united in fertilization to form the man, and in each column we must represent how that gamete was supplied in respect to each of the ingredients in our list. When the problem of heredity is thus represented we can hardly avoid discovering, by mere inspection, one of the chief conclusions to which genetic study has led. For it is obvious that the contributions of the male and female gametes may in respect to any of the ingredients be either the same or different. In any case in which the contribution made by the two cells is the same, the resulting organism — in our example the man — is, as we call it, *pure bred* for that ingredient, and in all respects in which the contribution from the two sides of the parentage is dissimilar the resulting organism is *cross-bred*."

We have already learned that in the Mendelian analysis there occur the terms "dominant" and "recessive" to describe characters which appear or do not appear, characters which are patent or latent in any individual. This contrast is not an essential part of Mendelism, but it is very notable, and needs explanation. The now accepted view of its cause is called the "presence or absence hypothesis", which was framed by Professor Bateson, and which he describes in the following words:

"We have got to the point of view from which we see the individual made up of a large number of distinct ingredients, contributed from two sources, and in respect to any of them he may have received two similar portions or two dissimilar portions. We shall not go far wrong if we extend and elaborate our illustration thus.

"Let us imagine the contents of a gamete as a fluid made by taking a drop from each of a definite number of bottles in a chest containing tinctures of the several ingredients. There is one such chest from which the male gamete is to be made up, and a similar chest containing a corresponding set of bottles out of which the components of the female gamete are to be taken. But in either chest one or more of the bottles may be empty; then nothing goes in to represent that ingredient from that chest; and if corresponding bottles are empty in both chests, then the individual made on fertilization by mixing the two collections of drops together does not contain the missing ingredient at all. It follows, therefore, that an individual may thus be 'pure bred' — namely, alike on both sides of his composition — as regards each ingredient in one of two ways, either by having received the ingredient from the male chest and from the female, or in having received it from neither. Conversely, in respect to any ingredient he may be 'cross-bred', receiving the presence of it from one gamete and the absence of it from another."

The interplay of qualities in one parent or both, a prime conception

"The second conception with which we have now to become thoroughly familiar is that of the individual as composed of what we call presences and absences of all the possible ingredients. It is the basis of all progress in genetic analysis. . . . A blue eye is due to the absence of a factor which forms pigment on the front of the iris. Two blue-eyed parents, therefore, as Hurst has proved, do not have dark-eyed children. The dark eye is due to either a single or a double dose of the factor missing from the blue eye. So dark-eyed persons may have families all dark-eyed, or families composed of a mixture of dark and light eyed children in certain proportions which on the average are definite."

Plainly, the reason why the dark-eyed people may have two kinds of families is that the dark or brown eye may be "pure", its possessor having received the presence of the factor from both parents, or "impure", its possessor having received the presence of the factor from one parent and the absence from the other. Brown is

dominant over blue because, on Professor Bateson's theory, brown is due to the presence of something the absence of which makes a blue eye; hence, if the brownness comes from one parent and the blueness (which is merely the absence of brownness) from the other, the offspring will have brown eyes, and we say that brown is dominant over blue. The "presence and absence hypothesis" beautifully explains this and a host of similar cases. But we cannot do better than quote Dr. Bateson himself. Having shown the double origin of constitution of the individual, and what it means, he proceeds to the next question:

The phenomenon which is the essence of Mendel's discovery

"So far we have been considering the synthesis of the individual from ingredients brought into him by the two gametes. In the next step of our consideration we reverse the process, and examine how the ingredients of which he was originally compounded are distributed among the gametes that are eventually budded off from him.

"Take first the case of the components in respect of which he is pure bred. Expectation would naturally suggest that all the germ-cells formed from him would be alike in respect of those ingredients, and observation shows, except in the rare cases of originating variations, the causation of which is still obscure, that this expectation is correct. . . . But when we proceed to ask how the germ-cells will be constituted in the case of an individual who is cross-bred in some respect, containing, that is to say, an ingredient from the one side of his parentage and not from the other, the answer is entirely contrary to all the preconceptions which either science or common sense had formed about heredity. For we find definite experimental proof, in nearly all the cases which have been examined, that the germ-cells formed by such individuals do either contain or not contain a representation of the ingredient, just as the original gametes did or did not contain it. If *both* parent-gametes brought a certain quality in, then all the daughter-gametes have it; if neither brought it in, then none of the daughter-gametes have it. If it came in from one side and not from the other, then on an average in half the resulting gametes it will be present and from half it will be absent. This last phenomenon, which is called segregation, constitutes the essence of Mendel's discovery. . . . It is this fact which entitles us to speak of the purity of germ-cells. They are pure in the possession of an ingredient, or in not possessing it; and the ingredients, or factors, as we generally call them, are units because they are so treated in the process of formation of the new gametes, and because they come out of the process of segregation in the same condition as they went in at fertilization."

Rules that are exemplified in heredity with remarkable exactness

"As a consequence of these facts it follows that, however complex may be the origin of two given parents, the composition of the offspring they can produce is limited. There is only a limited number of types to be made by the possible recombinations of the parental ingredients, and the relative numbers in which each type will be represented are often predicable by very simple arithmetical rules. For example, if neither parent possesses a certain factor at all, then none of the offspring will have it. If either parent has two doses of the factor, then all the children will have it; and if either parent has one dose of the factor and the other has none, then on an average half the family will have it and half be without it. . . . In such an observation two things are strikingly exemplified: (1) the fact of the permanence of the unit; and (2) the fact that a *mixture* of types in the family means that one or other parent is cross-bred in some respect, and is giving off gametes of more than one type."

Questions put to nature in her hidden world of life's renewal

"The problem of heredity is thus a problem primarily analytical. We have to detect and enumerate the factors out of which the bodies of animals and plants are built up, and the laws of their distribution among the germ-cells. All the

processes of which I have spoken are accomplished by means of cell-divisions, and in the one cell-union which occurs in fertilization. If we could watch the factors segregating from each other in cell-division, or even if by microscopic examination we could recognize this multitudinous diversity of composition that must certainly exist among the germ-cells of all ordinary individuals, the work of genetics would be much simpler than it is.

"But so far no such direct method of observation has been discovered. In default we are obliged to examine the constitution of the germ-cells by experimental breeding, so contrived that each mating shall test the composition of an individual in one or more chosen respects, and, so to speak, sample its germ-cells by counting the number of each kind of offspring which it can produce. But cumbersome as this method must necessarily be, it enables us to put questions to nature which never have been put before. She, it has been said, is an unwilling witness. Our questions must be shaped in such a way that the only possible answer is a direct Yes or a direct No. By putting such questions we have received some astonishing answers which go far below the surface. Amazing though they be, they are nevertheless true; for though our witness may prevaricate, she cannot lie. Piecing these answers together, getting one hint from this experiment, and another from that, we begin little by little to reconstruct what is going on in that hidden world of gametes."

The complexity of the arrangements by which some qualities are produced

Very early in these studies we discover that by no means all the characteristics of living creatures are due to the presence or absence of a single factor from their constitution. There are many features which require the concurrence of several factors to produce them; nevertheless, though the character appears only when all the complementary ingredients are together present, each of these severally and independently follows, as regards its transmission, the very simple rules we have already described.

Thus, for instance, there are two dwarf varieties of sweet-pea, the "Cupid" and the "bush", which, when crossed together, yield offspring of full height. As Professor Bateson says, "There is thus some element in the Cupid which, when it meets the complementary element from the bush, produces the characteristic length of the ordinary sweet-pea. We may note in passing that such a fact demonstrates at once the nature of variation and reversion. The reversion occurs because the two factors that make the *height* of the old sweet-pea again come together after being parted; and the variations by which each of the dwarfs came into existence must have taken place by the dropping out of one of these elements or of the other."

The repulsions as well as attractions that exist among the genetic ingredients

But the various Mendelian factors may have other mutual relations. The presence of one will often prevent or inhibit the development and appearance of another. Thus the factor for sex may prevent the appearance of certain characters, say in a female, though the factors for those characters are also present. Or, again, all the factors for the production of color may be present in a plant or an animal, but there may be a further factor present which keeps the individual white. If that one factor can be bred out, then the color will appear. Again, to quote Bateson:

"There are cases in which the action of factors is superposed one on top of the other, and not until each factor is removed in turn can the effects of the underlying factors be perceived. So in the mouse, if no other color-factor is present, the fur is chocolate. If the next factor in the series be there, it is black. If still another factor be added, it has the brownish-gray of the common wild mouse. Conversely, by the variation which dropped out the top factor, a black mouse came into existence. By the loss of the black factor, the chocolate mouse was created, and, for aught we can tell, there may be more possibilities hidden beneath."

Similarly, experiment shows that in many instances there is an antagonism or

repulsion between certain factors, so that if one of them goes into a germ-cell, the other never does, and thus an individual having the combination of the two characters in question cannot exist. This is illustrated in such organisms as sweet-peas, but it is also capable of illustration in the almost innumerable types of human nature. Human abnormalities, also, such as color-blindness, illustrate a further possibility. This condition is apparently due to the presence of some positive ingredient which affects the sight. "Just as nicotine poisoning can paralyze the color-sense, so may we conceive the development of a secretion in the body which has a similar action." But the general rule is that women do not suffer from color-blindness, though they may have color-blind sons. It seems that in a woman there is a positive factor which counteracts the color-blindness factor, though that is present, and the counteracting factor is probably the femaleness factor itself.

Such a survey of the "Methods and Scope of Genetics" clearly shows that this new science has a bearing on the problem of evolution, and in the final paragraphs of this remarkable lecture the importance of Bateson's work and that of his school for the science of life in general is asserted moderately but convincingly:

The results of genetic research so novel as to require time for interpretation

"The facts of heredity and variation are the materials out of which all theories of evolution are constructed. At last by genetic methods we are beginning to obtain such facts of unimpeachable quality, and free from the flaws that were inevitable in older collections. From a survey of these materials we see something of the changes which will have to be made in the orthodox edifice to admit of their incorporation, but he must be rash indeed who would now attempt a comprehensive reconstruction. The results of genetic research are so bewilderingly novel, that we need time and an exhaustive study of their inter-relations before we can hope to see them in proper value and perspective. . . . We cannot think yet of interpreting these complex phenomena in terms of a common plan. All that we know is that there is now open for our scrutiny a world of varied, orderly, and specific physiological wonders into which we have as yet only peeped. To lay down positive propositions as to the origin and inter-relation of species in general now would be a task as fruitless as that of a chemist must have been who had tried to state the relationship of the elements before their properties had been investigated."

Evolution not a problem at large, but one of critical analysis

"For the first time *variation* and *reversion* have a concrete, palpable meaning. Hitherto they have stood by in all evolutionary debates, convenient genii, ready to perform as little or as much as might be desired by the conjurer. That vaporous stage of their existence is over, and we see variation shaping itself as a definite, physiological element, the addition or omission of one or more definite elements; and reversion as that particular addition or subtraction which brings the total of the elements back to something it had been before in the history of the race."

"The time for discussion of evolution as a problem at large is closed. We face the problem now as one soluble by minute, critical analysis. Lord Acton, in his inaugural lecture, said that in the study of history we are at the beginning of the documentary age. No one will charge me with disrespect to the great name we commemorate this year if I apply those words to the history of evolution. Darwin it was who first showed us that the species have a history that can be read at all. If in the new reading of that history there be found departures from the text laid down in his first recension, it is not to his fearless spirit that they will bring dismay."

The organism a living mosaic, made up of a vast number of units

Such was the position of genetics as stated by its founder in 1908. Very great developments have occurred since then, by the use of the key and the methods provided by Mendel. We shall observe that, in one of the preceding quotations, Pro-

fessor Bateson excepts the case of what he calls "originating variations" — *i.e.*, actual novelties appearing for the first time in the history of the species. They remain the question of questions, and we must beware of supposing that Mendelism, or contemporary genetics, can solve it. Later we shall see what hope there is of contributing to its solution by specially devised experiments. Meanwhile, we have to deal with a theory, and a method, which gives us the key to the transmission, the combinations, the partings and recombinations of characters already existing.

Our present business is enormously to extend the range of facts which this key will enable us to ascertain. It gives us the idea of a living creature as a living mosaic, made up of a vast number of definite, characteristic units, which may be arranged and combined in many patterns. We have to analyze as many living creatures as possible, so as to define their mosaic constitution; and we see that the method of experimental breeding will reveal what the knife and the dissecting-table are quite inept for. Nothing but the genetic method could tell us that under the black coat of a mouse there is a chocolate coat, if the factor for blackness were not there to conceal it.

The genetic problem of the couplings and repulsions of the formative units

Only the genetic method can show us how the couplings and repulsions and complementary action of different factors affect the constitution and characteristics of living things. Only the genetic method gives us the key to all those forms of true variation which depend upon different shufflings and distributions of the factors in the germ-cells. Only the genetic method will enable us really to appreciate the influence of environment upon the development of the living creature, for until we know its natural possibilities we cannot estimate the action of nurture upon it.

Similarly, such terms as reversion, atavism, "throw-backs", "skipping a generation", and many besides, which have darkened counsel for decades, are being given a real meaning by genetics. We see that when two modern fancy pigeons are mated, and the offspring revert to the characteristics of the ancestral rock-pigeon, nothing more mysterious has happened than the coming together again of factors which were together in the ancestral form, but had been parted in the modern varieties. That is the simple and efficient explanation of true reversion. Other cases of so-called reversion, like feeble-mindedness in mankind, have been analyzed by the genetic method, and found to have nothing to do with reversion at all, but to be due to the absence of certain factors which condition the proper development of the nervous system, and which obey the laws of genetics in their transmission.

The unparalleled development of genetics as a branch of science

The rapidity of development in this branch of science is almost unparalleled, so efficient are a sound method and a sound theory. New researches are published every week, and the number of workers rapidly increases as men find how fertile this field is compared with such sterile stuff as the academic discussion of "natural selection". In the next chapter we must try to state, as nearly as possible, the established achievements of genetics at the present time. We shall find them substantial and suggestive; but we may as well warn ourselves against the supposition that any of these most recent elaborations of Mendelism throw a light upon the problem of problems, to which Professor Bateson can scarcely be said to have given adequate prominence in the lecture from which we have quoted. He indicates for us the essential discovery upon which his school is based, and qualifies his proposition by the words, "except in the rare cases of originating variations, the causation of which is still obscure". Let us duly note that these "originating variations", as Professor Bateson calls them, are the *sole material* of organic evolution, and that if he had described their causation as still utterly incomprehensible to mechanical science, instead of as merely "obscure", he would still more accurately have stated the limitations even of our newest knowledge.

THE DEFENSES OF PLANTS

How Plants that Live Near the Ground Ward Off
Their Enemies with Poison, Dagger and Subterfuge

THE STRUGGLE WITH THE ANIMAL WORLD

IN the world of animate nature, so long as things are not interfered with by man, the general rule of life is that the race is to the swift, and might is right. All observations upon living creatures in a state of nature impress upon our minds forcibly the conclusion that the struggle for existence is a great reality, and none but the fittest survive. True, there are examples of plants and animals living more or less in dependence one upon the other, but even in such instances the benefit derived is usually for one of the individuals at the expense of the other. The broad, true statement remains — that plants and animals make no effort to help any but themselves. Altruism is the last product of human, ethical progress.

This being so, and granted that the evolution of plants and animals has proceeded through the ages on the lines of natural selection of the fittest to survive, it can be understood that, in the case of plants especially, what constitutes the fittest will frequently be some special means by which the plant can protect itself against attacks from all sides. Unfortunately — from the point of view of the plant — the flora constitutes the principal source of food supply for the animals, and the plants are therefore in a constant state of exposure to risk of life and danger of extermination. Other dangers, too, have to be faced besides that of consumption for food, but that in itself is such an important matter that for the moment we may confine our attention to it.

In an earlier chapter we paid some attention to the composition, from the chemical aspect, of plant structures, and we noticed among other things that the chlorophyll granules have a very similar composition to that of protoplasm; moreover, by their action, sugar and starch are manufactured, and the cells containing the green coloring matter also contain easily digested carbohydrates. Now, it just happens that these are precisely the kind of foodstuffs upon which the herbivorous animals subsist. Moreover, the herbivorous animals choose for their special food principally the chlorophyll-colored tissues. It is here we see the incessant battle for existence between the plant and animal worlds. The animal, presumably, merely acts upon the instinct of hunger, and has not the foresight to reason that the result of his indiscriminate feeding upon the green parts of plants will destroy their capacity for producing food afterwards. Man acts somewhat differently because, although he destroys very large quantities of green plants for purposes of his own, he usually leaves enough either of the individual plant or a sufficient number of individuals to replenish what he has taken for himself. But this protection meted out to plants by the reason of man is, after all, only extended to a very few species — namely, those which he himself requires for his own food or clothing, or for some other product in civilization. If nothing else existed to save the plants, man's foresight would be unavailing, because so few of them, comparatively, interest him in a sufficiently practical way. The plants are therefore thrown back upon themselves for protection, and hence there have been evolved a variety of structures and processes that may be summed up in the term "plant defenses".

When we consider the thoughtless methods but too frequently employed by man in cutting timber from mountain sides, leaving them bare and unproductive, we may even argue that man himself has ample opportunity to improve in his "intelligent" treatment of plants.

Plant defenses are of very different kinds and degrees. Some of them secure the plant absolutely from almost any sort of attack, while others merely enable them to attain relative immunity. Other arrangements are not merely protective to the plant itself, but are of deadly danger to those whose temerity prompts them to interfere with it.

How do animals know how to avoid injurious plants?

Among the more formidable plant defenses *poisons* at once occur to the mind; and it is interesting to note that most of the plant-poisons are found only in those portions of the plant where they are necessary for protection. That is to say, plant-poisons occur chiefly in the leaves, the flowers and the fruits. Another point to be kept in mind is that the different poisons secreted by the plant do not all act to the same extent upon all animals. For instance, the leaves of the common poison ivy (*Rhus Toxicodendron*) are very poisonous to our touch, and yet these very same leaves are the food upon which certain insects flourish.

So here we have the curious case of a plant protected against external enemies by its leaves containing a very deadly alkaloid, while, at the same time, the plant can supply small parts of itself for food to a tiny insect without being entirely sacrificed. The insect merely eats a few holes in the leaves; it does not destroy the entire plant.

It is very difficult to imagine how animals become possessed of the knowledge which enables them to avoid certain poisonous plants. We say that it is in virtue of their inherited instinct, but how that instinct became evolved in these definite directions is not quite so easy to demonstrate. This, however, is not the place to discuss that topic.

In some cases poisonous plants have quite a distinct smell, and we can understand how they may be readily avoided. For instance, the thorn-apple, the common henbane, and the water hemlock have leaves the odor of which is distinctly disagreeable. But in quite a number of other cases no smell is noticeable to man until the leaf is bruised, yet these plants are just as carefully avoided by the animals of the field as is the more obviously dangerous group. In this last category may be placed the poison ivy and the hellebore. None of these is ever eaten by wild animals such as rabbits and deer so far as we know and all seem to be carefully avoided by the domesticated animals of the farm.

These plants, as we have said, have no perceptible odor — to us, at least — but it is, of course, possible that the more delicate sense of smell in the lower animals is sufficient to warn them of the danger. A further interesting point is that there are quite a number of plants not poisonous to man, but most scrupulously avoided by the herbivorous animals. In this list may be placed a number of mosses and ferns. Since these are so carefully avoided, the presumption may be that they would be injurious to the animals if partaken of. So that among the first of the defenses of plants against the attacks of animals must be the possession of poisonous qualities.

The indisposition of animals for feeding on plants impregnated with salts

Many plants have leaves so impregnated with salts of one sort or another, or mineral matter that they are either distasteful to animals or extremely indigestible. In the stems of the horse-tails, the leaves of the rhododendrons and in many of the evergreens found on our hills there is such a strong deposit of silica that they are not tempting morsels of food. The same is true of the plants composing much of the flora of the Australian bush.

One would not imagine at first sight that the presence of water would have the protective power in connection with plants, but there is one connection, at least, in which water is a protection. Grazing animals do

PLANTS POISONOUS TO ANIMALS

DEADLY NIGHTSHADE

THORNAPPLE

HENBANE

BARBERRY

MONK'S-HOOD

HORSETAIL

FENNEL

HELLEBORE

RHODODENDRON

not care to feed upon plants on whose leaves drops of water or dew are actually present. In response to this example of the immunity conferred upon such plants, some have developed quite a special capacity for retaining water in the form of dew. Among such plants are possibly the teasel or the compass plant whose leaves are so shaped that both rainwater and dew are retained at the bottom of the leaves in a little cup long after evaporation has dried the leaves of other plants in the immediate vicinity.

The many forms of prickle evolved as a defense

We next may turn attention to plant defenses in the form of weapons of armor, so to speak, structures exhibiting a distinctly threatening appearance, as if they said quite plainly: "Let him touch who dares." In this group we have the array of spines, prickles and thorns characteristic of so many plants. The distinction between these several defenses is that the spine is composed of actual wood, terminating in a sharp point; the prickle, on the other hand, is merely an epidermic structure, and contains no wood, though it ends in a point that is always strong enough to produce injury. Now, although all parts of a plant may possibly be more or less protected by spines or prickles, it will be found that they are especially arranged to protect the green leaves. If not actually on the leaves themselves, they are on those parts of the plant with which any animal attempting to injure the leaf would come in contact. The detailed position and size of these various protective structures evidently depend upon the kind of animals whose attacks are most to be feared, and the way in which the attack is likely to be delivered. So we find that the huge floating leaves of the *Victoria regia* are only protected on the under surface and at the margin, because only at these points are they liable to attack. Other plants are well protected during their infancy, so to speak, that being the time when they are most susceptible to danger. Once they reach such a height as to be beyond the reach of the mouth of the grazing animal, the thorns may disappear.

The arrangement hinted at above would show that some plants restrict their protective weapons actually to the site of danger, while others distribute their weapons in such a way that one part of the plant protects another, or the whole plant. Some, of course, such as some of the hawthorns, are so spiny as to have a distinctly formidable appearance.

Leaves of certain plants may have a number of little, sharp points projecting from the network; others may carry their armory at the margin, and these different structures, most of which are strengthened with silica, take the form of either prickles or hairs or bristles.

The leaf itself may be in the form of a needle, in which case it is termed *acicular*. It is an interesting point to note in passing that not only are such leaves very similar to needles in appearance, but in such parts of the world as are destitute of more perfect implements they are actually used by natives as needles. Plants with leaves of this type are particularly characteristic of dry, arid wastes and deserts, where, owing to the extreme paucity of vegetation, the green-leaf plants are subject to the attacks of animals. The highlands of Mexico are specially prolific in plants whose leaves terminate in a prominent thorn. These thorns are capable of inflicting extremely serious injuries upon any animal coming in contact with them. Other forms, like that of the aloe, occur in South Africa.

Another kind of defense is seen in the thistle, and plants of a similar nature. In them the leaves are all split up more or less, and have margins and ends with a very serviceable protection of prickles. Plants of this kind occur in widely spread areas. The result of the splitting up of the leaf is that there is not a great deal of green tissue left.

Arising from the actual surface of the leaf itself, as opposed to its point, we have the weapons in the shape of bristles, or barbs, whose points are generally very hard, from the presence of silica. A leaf the margin of which is protected in this way may be aptly compared to the edge of a saw with its teeth; and not only so, but it may actually be used in a precisely analogous way.

PLANTS WITH WEAPONS TO WARD OFF FOES

SEA-HOLLY

COW-THISTLE

FURZE OR GORSE

HAWTHORN

COLLETIA

SPINY OPUNTIA

BERBERIS

ALOE

DWARF THISTLE

One can easily imagine how such forms of green leaves would be distinctly distasteful to grazing animals, whose lips and tongues would readily be lacerated by such weapons. Cut-grass, Leerzia and other grasses may show blades so impregnated in this manner with silica as to be capable of inflicting very serious wounds if touched.

Everyone must have had experience of the annoying little weapons possessed by many leaves in the form of sharp-pointed barbs that stick into the skin when the hand is brought into contact with the leaf. A variety of this kind of protection is seen to perfection in our own common indigenous nettle. The weapon here takes the form of a stinging hair composed of one large cell, which readily breaks off and leaves a portion of itself attached. A very slight contact is sufficient to break such a hair, and the fracture leaves behind it an extremely sharp-pointed portion, from which exudes an irritating substance of the nature of formic acid, and this is injected into the skin of the animal or person handling the leaf. The process is very similar to the arrangement of a hypodermic syringe. Considerable inflammation may be caused in the skin as the result of breaking off a number of hairs in a small area and the injection of their contents.

LEAVES OF THE SAME HOLLY TREE WITHIN, AND OUT OF, THE REACH OF CATTLE

Everyone is familiar with the fact that if the nettle be handled in a certain manner these unpleasant effects may be avoided. It is possible to stroke a nettle with one's hand without being stung. For one thing, the lower part of the plant has no stinging hairs upon it. They are restricted to the foliage leaves. The hairs themselves are distinctly elastic, and can be pressed down so as to lie in close contact with the surface of the leaf. If, therefore, one grasps the nettle from below, and passes the hand upwards so as to press down the hairs on to the leaf, the hand will glide over them without causing any break in the hairs, and therefore without sustaining a wound. But, on the other hand, if the hand comes down on the leaf from above, the slightest touch breaks off the points of a number of the hairs, which pour out their poisonous contents. Here we have an excellent protective arrangement, therefore, against the depredations of grazing animals.

Thus far, then, we have seen that plant defenses may be in the nature of more or less offensive smells, which create a distaste in the animal for whom otherwise they might form food. The dog-fennel and the hound's tongue are plants whose smell is evidently much disliked by ordinary grazing animals. Secondly, we have noted that there may be contained in the leaf of a plant as well as possibly in some other parts of it, some extremely poisonous principle, generally in the nature of an alkaloid, as we get it in the water hemlock and the tobacco plant; and here, too, there is sometimes an odor associated with the plant which warns the animal of its nature, though sometimes the plant is odorless. Further, a great many plants have an extremely bitter, sour or acrid taste, sufficient to keep animals from troubling them. The leaves and shoots of the horse-chestnut and the maple are of this nature, and are avoided even by insects.

Not only the leaves, however, are thus protected, because when one considers plants such as the potato, the peppers, mustard and horseradish one sees at once that different parts of the plant, or, indeed, almost all of it, may be distasteful. In certain plants smell and taste combine to produce their effect, and this is probably the case in many of the bulbs, like the onion.

Then we have seen that plants in arid and desert places are principally protected by the presence of extraordinary developments in the nature of thorns or cutting leaves. Also we have noted that a large number of our own indigenous plants are provided with thorns (excellently seen in the hawthorn), or others may have pointed, barbed, stinging hairs. A still further protection is conferred upon such plants as have hard, flinty stems, or very silicious leaves, both of which are indigestible.

THE STINGING HAIR OF A NETTLE

This highly magnified photograph shows the hair in a single cell filled with protoplasm and acid sap, which flows out when the bulb at the tip is broken.

Plant defense, however, is not entirely a question of the provision of actual weapons. The plant is still not quite at the end of its resources, and may even turn to subterfuge, as it were, to protect itself. Thus we have very curious examples of what is termed *mimicry* in plants, the evident object being to suggest such a striking resemblance to something else as will cause the imitator to have his identity mistaken. Perhaps the best-known example of this process is that of the common dead-nettle. It takes this name from the fact that in general appearance it looks extremely like the common stinging nettle, though, as a matter of fact, it is quite devoid of such unpleasant properties. There are plants in South Africa which look like pebbles, while others are colored to resemble the earth.

THE STINGING NETTLE AND ITS MIMIC, THE RED DEAD-NETTLE

More peculiar still are the arrangements for self-protection in what are called the ant-plants, offering special inducements, as it were, to the ants to establish themselves upon these plants, or, rather, trees. True, some ants live upon vegetable food, but the great majority are animal-eaters, and destroy large numbers of insects. This has been turned to practical account by orange-growers in China, who deposit ant-nests in the trees, and construct bamboo bridges from one tree to another in order to allow the ants to pass.

A striking arrangement of this sort is to be found in an acacia, which provides special food for the ants at the end of its leaflets. The ants living on this material protect the leaves from any further attack. Indeed, the number of plants with some sort of arrangement of this sort in order to attract ants, and thereby incidentally to repel other insects, is extraordinarily large. This kind of relationship between a plant and an animal or a similar relationship between two or more plants or two or more animals where there is mutual benefit is termed *symbiosis*. A plant living in this way with ants is said to live symbiotically with the ants, the plant providing a lodging and nourishment, and the fierce little ants providing a standing army against caterpillars, beetles and snails. The actual protection may be carried out by the

ants hurling their excretion of formic acid against the unwelcome visitors. Sometimes ants might have a sort of symbiotic relationship with plant lice and destroy the plants through attempting to maintain a too large population of lice on a given plant. The corn-root louse, for example, is cared for by an ant which lays bare the roots of corn and other grasses and places the lice on the exposed surface. This helps the lice but hurts the corn.

A PSEUDO BULB OF AN ORCHID WITH AN ANT COLONY

The gardener wishing to protect a plant from the various smaller enemies of the animate world will sometimes surround his plant with water, standing the pot containing the plant in another containing the water, and so preventing the access of any insects that are not prepared to fly or to swim. Now, this isolation by means of surrounding water is, of course, found in the case of many water-plants, such as the water-lilies, and innumerable others, whose situation confers upon them an almost complete immunity from dangerous attack. The visitors that arrive in their search for nectar and pollen serve more frequently the useful purpose of fertilization, while the injurious snails and insects, such as the ants, etc., are effectively warded off. The same principle — though, of course, on a much smaller scale — is to be observed in plants which allow a slight portion of water to accumulate at the base of their leaves, as was suggested in the compass plant and teasel.

More common than even this last scheme is a mode of defense specially provided for the benefit of the flowers. We refer to the presence of extremely sticky secretions. Sometimes this secretion, which is excreted by the plant tissue, lies upon the surface, and entirely precludes insects from crawling over it. The sticky excretion often comes simply from the epidermis, and in other cases from special glands or hairs. The most common position for the protection of the flower is on the flower-stalk, or else the principal stem. A common example is to be found in the catch-fly, which takes its name from this very property. The protection derived from sticky secretions sometimes extends not merely to the flower, but to the whole foliage, as in certain of the primulas and saxifrages, on whose leaves the dead bodies of insects are frequently found adherent.

Then, also, it must be remembered that the wax-like covering, present in so many flowering parts, obviously is a means of protection to the flower from the entrance of insects. This, at any rate, is one part of its function. It is interesting to note, in passing, how varied plant defenses are to meet the attacking forces. Thus, a waxy exudate is no protection against a snail, for it will pass over it without any trouble. On the other hand, it is perfectly effective in the case of the hard-bodied little insects. They find in it an insuperable barrier.

When we come to consider the structure, nature and function of the flower itself, we shall have to refer again to this question of defense in connection with special parts of a flower. It will be sufficient to say here that most of the plant defenses, produced as protections against the winged insects,

are situated inside the flower, and are in the form of hair-like structures, arranged in a number of different ways. Then, again, the actual arrangement of the flower structure itself, especially as it affects the hiding and protection of the nectar is often extremely ingenious.

Lastly, we may refer to the mechanical arrangements devised by plants to protect their stems and leaves against insects which would creep up them from the earth. One of the most ingenious of these arrangements is that occurring in some of the balsams, in which the sweet exudate secreted by the leaves, or in their vicinity, obviously protects the nectar of the flower, this flower-nectar being required to attract pollinating agents. There is a special gland developed from the stipule at the base of the leaf, which secretes the sweet exudate and attracts insects on their path upwards. They come in contact with a drop of sweet exudate at the base of every leaf, sweet exudate as good as the nectar found in the flower, and closer at hand. Ants, therefore, in search of nectar, go so far, and no farther. In the absence of such provision, they would, of course, search out the nectar within the flower itself, and would thereby interfere with the visits of those winged insects whose arrival is necessary in order that pollination may be effected and the plant's spread extended.

THE CATCH-FLY AND ITS VICTIMS

Then it must also be remembered that all the many and varied devices to be found in plants, by means of which insects are attracted and guided to different portions where they find food provided for them; all the various arrangements of petals, which assist in cross-pollination; all the manifold provision for the dispersion of seeds and fruits; all the protective structures of seeds and fruits, as well as an infinite number of other considerations, might very well be regarded as coming under the general heading of plant defenses. Defense is always such a varied problem, involving not only the repelling of enemies but the attraction of friends, that it is not at all surprising that our plants should show and use not only these many types discussed but many others as well, often of the most amazing ingenuity.

THE WELL-DEFENDED PRICKLY CACTUS OF THE ARIZONA DESERT

A CONFLICT BETWEEN AN ADULT WALRUS AND TWO POLAR BEARS

The photographs on these pages are by Lewis Medland, W. P. Dando, J. Bell and others.

FIN-FOOTED CARNIVORES

Intelligent and Affectionate Creatures Hunted with Ruthless Cruelty between Land and Sea to Decorate a Lady

BLIND EXTINCTION OF ANIMAL RACES

THE limbs of animals possessing backbones are derived from the fins of their fish-like ancestors. The seals are fin-footed. Are they, then, to be reckoned highly specialized fishes? It is hardly a conclusive answer that the true seal, a prince of the waters, has, when young, to be taught to swim, and cannot, therefore, be descended from a fish. The genealogy of the seals must be sought in other directions than this, though the fact, taken in conjunction with others, has a decided value. It is easier to convince the skeptic of the true mammalian character of the seals than of the whales. The seals make their living in the waters, it is true, but they are simply flesh-eating, water-dwelling mammals.

Scientifically they are classed as a suborder of the true carnivora, and, with the latter, constitute the fourth mammalian order. We can trace them as far back as the Miocene period, but no further; and, although they present certain resemblances to living animals, as to the bear, and, more particularly, to the sea-otter, the resemblance is purely superficial, and has no true significance.

The seals are directly descended, it is thought, from primitive carnivores, the creodonts, which were swept out of existence in the stress of competition with the animals of more highly organized brain from which the true carnivora developed. The ancestors of the seals and walruses were driven into the waters. They left the land as four-footed animals, possessing the same number and arrangement of bones with other carnivores.

Their limbs have undergone a strange transformation, with the result that, although the five digits remain to each foot, all four of the latter have become modified into paddles, or fins, still serviceable for progress, of a shuffling sort, on land. We use the term "fin" for lack of a better, but, except in the true seals, which have the most degenerate of hind limbs, the fin-like function of the feet is more apparent than real. The limbs are inclosed up to the wrists and ankles by the skin of the body, but, whereas the true seals have the hind feet thrust straight out and backward, the eared seals can, by arching the body, draw the hind feet under them, and employ them for land travel. The true seal, on the other hand, when it leaves the water, brings the under part of the feet together, like the hands of a man about to take a header into the water.

But, it may reasonably be asked, why, when the whole build of the seals and walruses is so remarkably adapted to an aquatic existence, should there be this retention of limbs for land travel? The reason is that the members of all three families are born land animals. Man walks before he can run; the pinnipeds walk, so to speak, before they can swim. The presumption is that when the ancestors of the fin-foots first took to the water they were as agile on terra firma as most other carnivores. But in the unending and sanguinary struggle for a living they had brain enough to discover that the path of least resistance lay in the waters, and they naturally betook themselves to that path.

They must have been animals of a high order of intelligence, for it is to be supposed that their life in the sea would not so highly tax their mental capacity as to have necessitated the really fine brain which they now possess, and which makes them highly educable. Strange as it may seem, these creatures, whose way lies in the vasty deep, are, under favorable circumstances, more easily domesticated than almost any other animal, and show remarkable affection and intelligence. Perhaps it is because the captive seal is more under observation than the free animal, but it always seems as though the intelligence of these animals finds its highest expression when in association with man, and not when at liberty.

The lack of sufficient adaptability in seals to escape disease

For all their wonderful brain, the pinnipeds when at large display the greatest stupidity at times, and, even when not pursued by man, fall victims in thousands to their blind persistence in seeking sandy shores as breeding places, where the young become infested with a species of roundworm (*Uncinaria*). The eggs of this parasite lie dormant throughout the winter in the sand of the breeding places of the fur seal. When the seals return from their winter migration, the eggs become attached to the fur of the adult seals, and pass from the body of the female into the interior of the infant seal, where they develop and multiply, at the cost of the young seal's life, feeding upon the blood of the animal until the latter dies of anæmia.

This parasite cannot exist on rocky rookeries, but the intelligence of the seal falls short of reasoning power enough to grasp the danger to its kind from sandy nurseries, and the lives of thousands of young seals yearly pay forfeit. An animal whose feelings are sensitive enough to induce it to shed actual tears of woe when ill befalls its young, which happens in the case of the seals, might perhaps be expected by this time to have learned to avoid these death-traps. But then we might also expect seals to avoid bringing forth their young upon land at all, and so escape the hideous slaughter inflicted by man. It is quite likely, however, that the land parasite would be equal to the task of changing its habitat too, as has the flea that once flew; and continued residence in the sea would not bring immunity from man, as we shall presently see. If we could give the seals a few million years free from man-persecution, and with no enemies worse than parasites and such animal foes as the polar bear on land, the shark and the grampus and other deep-sea terrors in the waters, they would probably make themselves masters of a wiser way in life. But that is beyond the best of us.

Our present suborder embraces three families. The first is the eared seals, and is made up of the sea-lions and sea-bears. The next consists only of the walrus; while the third is divided into nine genera, the last being the mighty sea-elephant. The first family, then, is that of the sea-lions and sea-bears, of which there is one genus, comprising nine species. There is no difficulty in distinguishing members of this genus from the true seals. They have distinct external ears; the true seals have not. The eared seals have a well-defined neck, and their hind feet turn forward, not outward in the manner of the true seals.

The curious diversity of habits in the sea-lions and the true seals

The sea-lion has a coat of close hair, and is sometimes termed a hair seal; the sea-bear has a close, woolly undercoat beneath the long hair, and this is the fur seal. The long hairs are removed by the furrier, and the beautiful undergrowth remains as the fur of commerce. Sea-bears and sea-lions frequent the same shores for breeding, though not seeking the same sites; and the genus is widely represented in both the northern and southern hemispheres, though missing from the North Atlantic.

Sea-lions, using the term to describe the whole of the eared seals, differ in habit from the true seals in that they pass a good deal of their time on land, and make regularly for fixed breeding places, where each male becomes, or seeks to become, the lord of a flourishing harem.

VICTIMS OF EXTERMINATING LUXURY

THE NORTH ATLANTIC GRAY SEAL ON THE WATER AND ON A BANK

A PAIR OF CALIFORNIAN SEA-LIONS OF THE NORTH PACIFIC OCEAN

A SOUTH AFRICAN SEA-LION

A YOUNG SEA-LION

The sanguinary battles of the sea-lions in the mating season

The true seals, on the other hand, do not undertake these long migrations, but rear their young upon land, or upon ice-floes near which they may happen to be. Moreover, they are for the most part strictly monogamous. A "rookery" of sea-lions has often been described, but the picture is strange enough to warrant a brief recapitulation.

The bulls arrive first at the breeding grounds, toward the close of May or the beginning of June. The females follow about three weeks later. Each of the strongest bulls takes his own station, some ten feet square, and to this he seeks to cajole or bully the fairest of the opposite sex. But as many beating hearts may be set upon one and the same acquisition, the right to possession can be decided only by sanguinary combat. The males nearest the sea make their choice there, and haul their loves high and dry to land. But as another female appears at the water's edge, the gallant male goes to her assistance too, and in his absence a second bull steals the unguarded cow, only perhaps to lose her to another rival. And this sort of thing continuing, the female, first settled upon a water-line station, may find herself finally deposited in a seraglio fully 150 feet inland, having in the meantime been hauled from station to station by upward of a dozen rival males. Each transference causes a battle, and the life of the sturdy old bulls down upon the coast is one long round of engagements until the last female has come ashore.

The fighting is done with the mouth. The rivals spar and feint with averted heads, then thrust out their long necks and fasten on with their powerful teeth. Once the jaws close they do not reopen; the flesh must tear. Gouged eyes, flippers torn to ribbons, and hide and blubber sorely gashed mark the price which the victor has paid for his many victories. There are always more males than harems. The unsuccessful are driven inland, among them some who have set up housekeeping and then been ejected after battle.

Soon after their arrival, the females give birth each to one young one, or, rarely, two. Then they are at liberty temporarily to revisit the sea in quest of food. They do not desert their little ones, but return to feed them, and it is a well-established fact that the mother can distinguish the cry of her own pup or calf from a host of others and go unerringly to it. It is while the mother is on these feeding expeditions that such cruel havoc has been wrought by seal-hunters, who slay the animals in the water. Of course, at such times only females are on the move. The males never leave land from their first arrival, but pass, it may be, four months on shore without food or drink. Here it should be mentioned, by the way, that the sea-lions do not drink, in the ordinary sense, but are content with such moisture as adheres to the fish that they eat. True seals do drink, occasionally. To return, however, to the matron in the midst of the sea.

The quest of the pelagic sealer is not confined merely to the breeding months proper; it extends over the period during which the seals are making their way to the breeding grounds, at a time, of course, when the females are about to bring forth their young. Those that then escape have to run the gauntlet whenever they go out to feed, and as the distance covered extends to between a hundred and two hundred miles the danger is considerable. Every female killed at such a time represents the loss of three seals — the mother, her young one on shore, and a further young one which should be born in the following summer. For, very soon after the birth of one little seal, the matron has expectations of a successor. Therein lies the mischief and much of the horror of the trade. For every female seal killed under such circumstances there is a pup seal left to die of slow starvation on shore, and there can be no possible doubt that the official estimate is well within the mark when it states that the ocean catch of 27,000 and odd skins in a recent year represented a loss to the herd of over 75,000 animals. It is from the slaughter of these seals at sea that the genus has been driven so far on the road to extermination.

But it has brought a wonderful thing to pass. The nations interested have met and agreed upon a close time for fifteen years. Not a seal is to be taken in the ocean by any ship flying the flag of one of the signatory Powers until June, 1926. Those Powers are Great Britain, Russia, Japan and the United States. It is a remarkable agreement in more ways than one. In the first place it recognizes the fact that, of all the old breeding haunts of the fur seals, only two remain of any real commercial account, and those are the Pribylof Islands, Alaska, belonging to the United States, and the Commander Islands, in the Behring Sea, belonging to Russia. Other ancient strongholds have been desolated, so much so that seal nurseries owned by Japan are not deemed even worthy of mention. It is sad that there should have to be this admission in an international treaty.

The second remarkable aspect of the compact is this: that four great Powers have had to confess that unless old methods are summarily inhibited, the fur seal will soon be as dead as the dodo. And to prevent this we have the extraordinary spectacle of two Powers buying off the other two. Russia and the United States say to Great Britain and Japan: "If you will cease catching seals in the sea and leave the business to us on land, we will repay you to the extent of 15 per cent of our catch." To that course the other two nations agreed, and the bargain came into effect in 1911. But, be it noted, this applies only to the fur seal, not to the true seal. Commercial prudence, not pity, has dictated the move.

THOUSANDS OF ALASKAN SEALS ON A BEACH BESIDE THE BEHRING SEA

There is an enormous market for sealskins. The United States has made a double profit on them, first by their sale, secondly by import duties after they have

been returned from dressing in England. We paid, approximately, $7,000,000 for the Alaskan territory, and for twenty years received from sealskins alone more than twice that amount. But in those days the seal herd numbered 2,500,000 with vast potentialities of increase. Insensate slaughter on sea and land — 80 per cent, it is computed, at sea — brought down that splendid herd, in less than thirty years, to 185,000 seals. Another year or two of unchecked slaughter would have seen the end of the genus of northern fur seals. And that is why this unusual international treaty was effected. Now the sealing is in American and Russian hands. The arrangement is that only the superfluous males will be killed, and those at the breeding places, when sex can be instantly determined before the lethal blow is struck. But the Powers ought to have gone a step beyond the dictates of mere commercial prudence; they should have spoken one word, at least, in pity.

THE MONK OR MEDITERRANEAN SEAL

There is no more sickening chapter in the pages of commerce than that relating to seal-hunting. It is a sanguinary, brutal, disgusting business, and if the details were but known and realized it would make us all forever forswear sealskin. The hunters descend upon these lonely nurseries, head off the seals from the water, and drive them like sheep inland to the killing grounds. The wretched animals, all unfitted for land travel are driven over miles of rocky, broken track. Panting, struggling, foaming at the mouth, falling exhausted by the way, they are urged forward, and when at last they come to the appointed place they are made to pass between men armed with bludgeons. With such force are the seals struck that, according to an official publication, "the crystalline lenses of their eyes fly out from the orbital sockets like hailstones".

Equally shameful is the treatment of pregnant seals, which, out of coat themselves, and therefore useless, are killed in order that there may be obtained the fœtal sealskin, which is more prized for its softness and delicacy than all other forms. Surely, if facts such as these were driven home to the public mind, the sealskin would no longer be the hall-mark of affluence and prosperity. But it is these things which make us wish that the treaty included one word of pity for the animal itself. Commerce, not humanity, speaks in the epoch-marking agreement. There is nothing new in that, of course; more than a century ago the Russian Fur Company threw into the water at Unalaschka, their then chief fur-trading station, 700,000 skins, "in order not to glut the market".

Sandwiched between the eared seals and the true seals come the walruses, huge sea animals, larger even than the largest of the sea-lions, though these latter attain a length of 13 feet and a weight of 1300 pounds. It is in bulk rather than in length that the walrus exceeds the sea-lion, large specimens being estimated at as much as 3000 pounds. Like the eared seals, the walrus turns its hind feet under the body to assist it when on land, but its tusks constitute the feature by which even the tyro can immediately identify it. These tusks, which are of dense ivory, are produced from the upper jaw, and measure from 18 inches up to 32 inches. The habits of the walrus are less well understood than those of the seals; butchers, not nature students, are, as a rule, its human visitors. It is well known, however, that the tusks act mainly as weapons, and perhaps are employed in rooting among sediment and weeds for the small marine creatures which, with molluscs, form its diet. The teeth are few in number, and reduced to mere pegs, barely

clearing the surface of the gum. Restricted now to the coldest waters, the walrus at one time had a considerable range. Today it is one of the dying groups. Its icebound home is no sanctuary. Its blubber yields abundant oil, so the animal must die.

The walrus is quite harmless unless attacked, when a male will fiercely retaliate, and overturn the stoutest boat. Many cases are recorded of walruses acting in concert in these circumstances, after one of their number has been injured; and at such time they are foes much to be feared. They betray considerable solicitude for a wounded comrade, and hunters take advantage of this to slay all within reach; the animals that might escape unwounded remain to help the injured, and all fall victims to their persecutors.

A YOUNG AND TUSKLESS WALRUS

Hagenback, who has had fortunate experiences of young walruses in captivity, mentions an instance in which a certain sea captain, of whom he was in the habit of buying captured walruses, discovered on the coast of Northeast Land, 370 of these animals, all females. "Every one of them was slaughtered by five ships' crews." It would be interesting to know whether this incident has any connection with a crime against nature cited by Lieutenant-Colonel William Wood in an address delivered before the Commission of Conservation at Quebec: "Not so many years ago some whalers secured a lot of walrus hides and tusks by having a whole herd of walruses wiped out, in spite of the fact that these animals were at that very time known to be the only food available for a neighboring tribe of Eskimos. The Eskimos were starved to death, every soul among them, as the government explorers found out."

The earless, or true, seals, distinguished by characteristics which we have already considered, are a very varied group, divided into nine genera, including the mighty sea-elephant. Although they lack that extraordinary faculty of the sea-lion for balancing things on the end of the nose, they are remarkably educable and mentally alert. There seems little doubt that they have a genuine liking for music. Church bells, flinging their melody out from the cliffs over the seal's sea home, always draw these animals to the shore; while the sound of melody from ship or boat proves equally attractive. There is the suggestion that curiosity, not appreciation of harmonious sound, may account for this oft-noted phenomenon, and it is disappointing to learn that of all the animals experimented upon by musicians at the Zoo, the seals alone remained indifferent.

The true seals are to be found — in sadly diminishing numbers, it is true — in most seas, the majority favoring the northern hemisphere, where they produce their young, as a rule, on the ice. They ascend tidal rivers, but are mainly marine in habit, of course. But there is this remarkable fact about the distribution of the seal: that distinct species are found in the inland Caspian Sea, in the great Lake Aral, and in Lake Baikal, which, after the Caspian and Aral, is the largest body of inland water in Asia. The supposition is that the presence of seals in these waters indicates a prior connection with the sea.

But seals can travel on land, if necessary, — a short way in a long time. It is recorded that a gray seal traversed fully thirty miles of snow-covered land in Norway, the time taken, it is believed, being about a week. Whether they would have endurance enough to find their way from some other watercourse to the inland seas mentioned is, of course, another matter.

Many seals are destroyed on land by polar bears, and many in the waters by killer whales. But the shark is also an enemy of this animal. The common seal along our coasts is called the "harbor" or "leopard" seal. It is one of the smallest of the true seals, rarely exceeding a length of five or six feet, and is whitish in color, heavily spotted with gray. It sometimes finds its way into the Great Lakes or other inland bodies of water having a connection with the sea, but it is nowhere regarded with friendly interest by fishermen whose nets it frequently robs or even destroys in its pursuit of fish. It is found in both the Atlantic and Pacific as far south as North Carolina and Lower California though not abundant south of Maine and British Columbia. It is not as gregarious as other seals and, therefore, in no present danger of extermination.

Considerations of space preclude detailed mention of the various genera of true seals, but the sea-elephant, or elephant-seal, must be noted. This is indeed a prodigious beast, with a length of from 20 to 22 feet, and a girth of from 15 to 16 feet, these dimensions relating to males only, for the females are considerably smaller. The enormous coating of blubber by which the animal is enveloped is a perfect protection against cold, for it has been found that the body of a sea-elephant that has lain for twelve hours in the icy water of the Arctic fully retains its internal heat. Formerly to be found in enormous herds, the sea-elephant is now rapidly becoming extinct, and one species, the Californian sea-elephant, was nearly exterminated a few years ago. This aroused a good deal of controversy at the time. The last remaining few made their final bid for life on the island of Guadalupe, off the coast of Lower California. There was no law in the world to protect them; it was certain that, if left alone, within a very short time they would be slain by whalers and reduced to oil. There was not an adult specimen in any museum in the world. A rich English collector sent out an expedi-

FEEDING A HERD OF YOUNG WALRUSES IN STELLINGEN PARK, NEAR HAMBURG

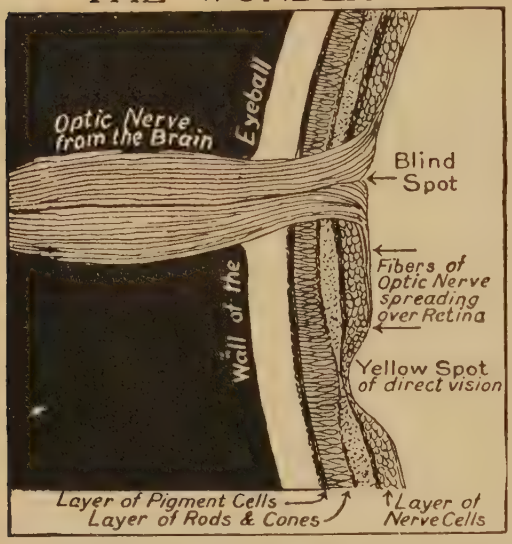
tion, had them photographed on land as they lay, then had them killed and brought home to be preserved in museums. It was a race to get them. On the one hand, there was a party of Mexican concessionaires who were to slay and boil down every seal and sea-elephant on the island; on the other, there was a keen naturalist collector. Fortunately some of the sea-elephants were elsewhere at the time of the slaughter so that when the island was revisited by an exploring party in 1919, a small band of the enormous beasts were found still holding their own. They are a vanishing race, however, and unless some measures are taken for their protection, they will soon vanish from the earth. It is right that we should have specimens in our museums but the law ought to declare that never should it be necessary to kill the last of a species to preserve its mummy for the knowledge of mankind. Science should have its representative of every living thing, but there should be no necessity for the *last* to be taken. The nations should declare that the last shall never be reached of any species of animal in the world, if by staying the cruel and rapacious hand of man such a disgraceful contingency can be avoided. It is not suggested, of course, even by the most ardent naturalist, that the entire seal family should be granted an immunity from capture for commerce enjoyed by few other mammals. Seals work havoc on fishing-grounds, and the Danish government until recently paid a sum for every seal destroyed in its waters. In a case of that sort the seal is a rival to man in his industry and quest of food; and were it left to increase unchecked in all waters it would eventually constitute a serious danger to our supply of fish. The condition has not the least possibility of arising; the true seals have no friend at any court, and seem doomed to almost certain extinction unless they, too, can be granted a small sanctuary where, unmolested, the naturalists of future generations can find them in their natural state.

ELEPHANT-SEALS AT THE CROZET ISLANDS

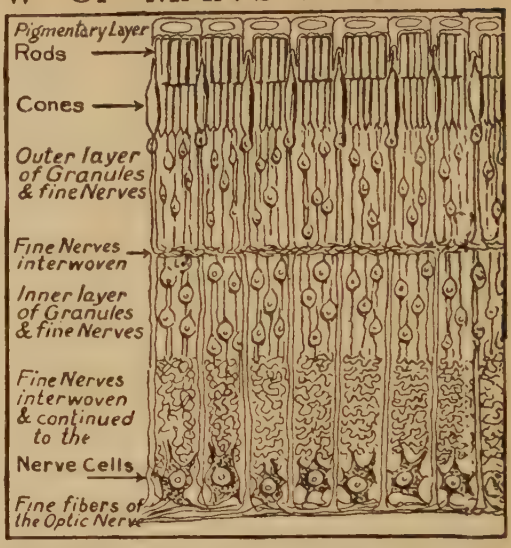
A BABY SEA-ELEPHANT

THE FALKLAND SEA-ELEPHANT, WHICH LACKS THE WELL-DEVELOPED TRUNK OF THE CALIFORNIAN SPECIES

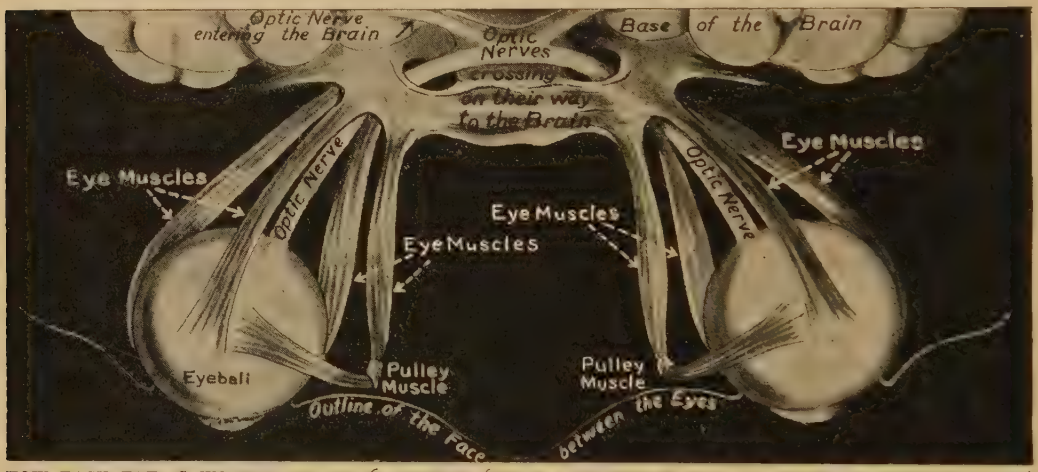
THE WONDER-WINDOW OF MAN'S BRAIN


Optic Nerve from the Brain
Eyeball
Blind Spot
Fibers of Optic Nerve spreading over Retina
Wall of the
Yellow Spot of direct vision
Layer of Pigment Cells
Layer of Rods & Cones
Layer of Nerve Cells

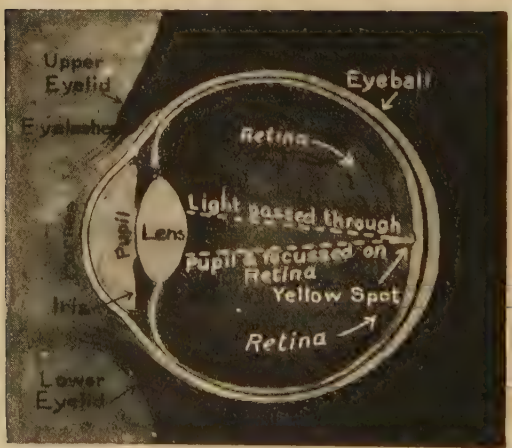
A SECTION OF THE EYEBALL THROUGH THE BLIND SPOT AND THE OPTIC NERVE


Pigmentary Layer
Rods
Cones
Outer layer of Granules & fine Nerves
Fine Nerves interwoven
Inner layer of Granules & fine Nerves
Fine Nerves interwoven & continued to the
Nerve Cells
Fine fibers of the Optic Nerve

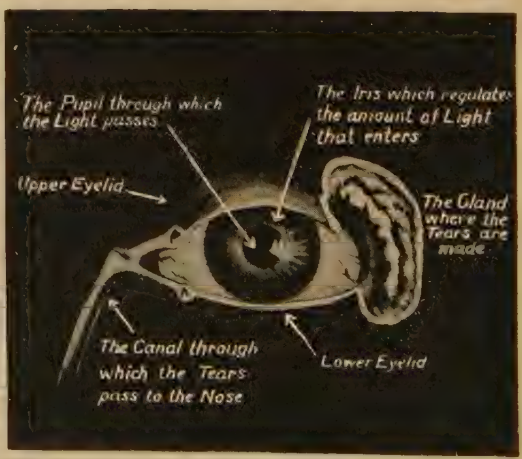
THE NERVE LAYERS AND RODS AND CONES THAT FORM THE RETINA — HIGHLY MAGNIFIED



HOW EACH EYE IS WORKED BY ITS 6 MUSCLES (ONLY 4 OF WHICH CAN BE SHOWN IN THIS DIAGRAM)



HOW THE LIGHT IS FOCUSED ON THE RETINA IN A PERFECT EYE


The Pupil through which the Light passes
The Iris which regulates the amount of Light that enters
Upper Eyelid
The Gland where the Tears are made
The Canal through which the Tears pass to the Nose
Lower Eyelid

THE GLANDS AND DUCTS THAT CLEANSE THE EYEBALL OF THE LEFT EYE

THE EYE AND VISION

The Marvelous Mechanical Contrivances of the Eye for the Transmission of the Materials of Sight

HOW THE BRAIN SEES, RECALLS AND CREATES

THOUGH perhaps not the most ancient, vision is in many ways the most important of the senses, and particularly so for the psychologist, since vision illustrates most clearly and in the highest degree all the stages from simple sensation up to perception and artistic creation. The eye and the visual apparatus are themselves, of course, part of the body, but we have purposely left over their discussion, and that of the other organs of sense, in order to deal with them from the psychological point of view. We have already learned, however, that visual sensation has its "cortical representation" on the outer and inner surfaces of the occipital or hindmost lobe of the brain. Everything that we are about to study, though of high order and largely composed of nervous elements, is to be looked upon as subsidiary to the center of vision in the cortex cerebri. If that center be thrown out of action, blindness is the result. No vision is possible unless the cortical center, and the nerve fibers which run backwards straight through the substance of the brain until they reach it, are intact. We further note the fact that no *light* travels along these nerves or reaches the visual center, which remains in absolute darkness, though it alone sees. The waves of light which enter the eye are arrested at the curtain at the back of the eye, called the retina. Some of the light is reflected; the greater part is absorbed, and excites changes in the nervous elements of the retina, which in turn send nerve impulses through the optic nerve, or nerve of vision, which proceeds backwards towards the visual center. But no light travels even along the optic nerve.

The fact is that the particular kind of sensation we term vision is the peculiar property of the nerve-cells in this area of the cortex. If they exercise their function, we see. Commonly and normally they are excited by light, but that is not essential; and perhaps the best proof of the fact that no light travels along the optic nerves and back to the brain when we see is that vision may be aroused by other means than light. Whatever agent excites action on the part of the cells in the visual area will produce in us sensations of vision. These sensations may be thus aroused from without or from within. If the eyeball be struck, we are said to "see stars", and in this case the mere shock to the retina, and perhaps the sudden raising of the pressure within the eyeball, has excited impulses in the optic nerve, and we have sensations of vision without the action of light. Again, in dreams, in day-dreams, in reverie, or at any moment that we will, we have sensations of vision apart from the action of light. At such times as these, remembered things

> . . . flash upon that inward eye,
> Which is the bliss of solitude.

This "inward eye", as Wordsworth called it, is of course the visual area of the cortex; and there is no doubt that when we have visual memories, or visual hallucinations, it is this area of the cortex that is thrown into action. In dreams and nightmares vision usually plays a large part; and the explanation here is that the visual area, perhaps much overworked and excited in the normal way during the day, does not wholly rest, as it should, during sleep, but indulges in eccentric activities of its own,

the results of which are visual sensations on our part, though we are asleep, with closed eyes, in the darkness. This remarkable fact about the visual area is not peculiar to it, for the facts of the other centers of special sensation are the same. No sound reaches the nervous center of hearing, but only nerve impulses that run along the auditory nerve. That nerve may be excited by many agents other than sound, but, whatever excites it, the result is the sensation of hearing. And, further, the auditory center may be excited in dreams, in reverie, and in the processes of memory, so that we hear, more or less clearly, either sounds which we have never heard, or sounds which are recalled by the memory, though all the time we are in silence. Thus there is an inward ear, exactly as there is an inward eye. All sensations of vision and of hearing, whether excited by actual light or sound, or by abnormal disturbance of the optic or auditory nerves, or by subtler and deeper causes, have their seat in those cerebral centers; and any activity of those cerebral centers must result in vision or hearing respectively, and in nothing else. Our clear understanding of this "law of specific sensations" we owe to the great German pioneer Johannes Müller.

The formation of the retina from the protrusion of the primitive brain

But normally, of course, the visual center is thrown into action through an astonishing apparatus, which we briefly summarize as the eye. This apparatus is definitely of double origin, in part lofty and in part humble. When we study the deeper parts of it, we find many cells which are plainly nerve-cells, but in front of these the eye consists of cells of lower type.

The fact is that the front parts of the eye, such as the lens, were developed from an infolding of the ectoderm, the outer germ layer, in a very early stage of development; but the back parts of the eye, especially represented by the retina, are formed in man and the higher animals not from the body ectoderm but from the brain itself. Very early in development a protrusion appears from each side of the developing brain.

Now these two protrusions grow each one on what is practically an ever-lengthening stalk. As each advances, it meets the depression or infolding of the surface ectoderm, which has been passing inward to meet it. Thus the eye is formed, the retina being derived from the protrusion from the primitive brain, so that its nerve-cells are really brain-cells, as if a portion of the brain had come out of the cranium in order to see; and the stalk upon which this protrusion or bulb of nervous matter was borne becomes the optic nerve.

The bony protection of the eye from external dangers

Everything in front of the retina is therefore to be looked upon as subordinate in function to the nerve-cells of the retina, which are, so to speak, personally affected by the rays of light for which the front parts of the eye merely exist in order to transmit. This transmitting apparatus first claims our attention, but we need deal with it only briefly, as its functions are wholly mechanical, and the problems of psychology lie further back.

We note, then, the well-protected position of the eyeball within a bony chamber called the orbit, through the back of which the optic nerve passes outwards from the cranial cavity. The edges of the orbit are powerful and project very efficiently, so that a "black eye" commonly involves anything but the eye itself. The bony roof of the orbit is thin, however, and upon it rests part of the frontal lobe of the cerebrum. A carelessly handled umbrella may quite possibly penetrate this delicate roof of the orbit, and cause death by its action on the overlying brain. The eyebrows add further protection of a different kind, by diverting the perspiration from the forehead, so that it does not run into the eye. The eyelids are provided with hair for a similar purpose. When the eye is open the upper lid is held up by the pull of a tiny muscle attached to the back of it. When this muscle ceases to act, the upper lid drops of its own weight, and the eye is closed. But the entire eye is surrounded with a circular muscle, one of the muscles of the face, which is also attached to the lower

lid; and by the action of this muscle the eye can be actively closed and screwed up in certain states of emotion. Normally, however, the closing of the eye is simply the cessation of muscular action.

More remarkable is the regular and rhythmic fashion in which, during waking, the action of this muscle is momentarily arrested and then resumed. The arrest results in a momentary fall of the lid, which is then immediately raised, and this is what we call winking. It is a reflex action, dependent upon sensations of incipient dryness derived from the front of the eyeball, but it is scarcely an ordinary reflex action, though it is commonly so described, for the response here is, in fact, not an action, but inaction; not stimulation of a nerve, but inhibition of it. This is a very simple case, but a very significant one, for there is reason to suppose that a great many other acts, including even what can only be called acts of the will, are essentially inhibitions, as this is, and consist in forbidding what has hitherto been permitted.

The important part played in the eye by tears

The function of winking is clear. The front of the eye must be kept moist, with a thin, regular pellicle of fluid covering it both for clearness of vision and for the protection of the delicate surface. For this purpose there exists, under the upper eyelid, towards its outer side, a gland known as the lachrymal gland, which secretes from the blood a clear, saline fluid, practically what the physiologists call "normal saline" or "physiological salt solution", known in ordinary language as tears. The ducts of the lachrymal gland lead the tears to the under surface of the upper lid, and each time the lid is dropped it sweeps the front of the eye with a tear. How important this is for the eye is only known to the oculist who has to deal with cases where the secretion of the tears is interfered with. At the inner end of the lower lid there is a minute aperture through which the tears drain downwards into the nose. If this be blocked, or if the secretion of tears be over-abundant, they drop over the lower lid and run down the cheek.

The various structural parts of the front of the eye

The eyeball itself has a hard and dense outer coat, the "white of the eye", which is called the sclerotic coat. In the front of this there is inserted a circular transparent window, horny in consistence, which is hence termed the cornea. This cornea has a marked forward vexity, which is of much importance for vision. It should be neither too convex nor too little convex, and the degree of its convexity should be equal in all directions. Otherwise rays of light, say from the two limbs of a cross, will be unequally bent, and the condition called astigmatism will result. The cornea itself should be absolutely transparent and colorless. Inflammation of its surface, such as often attacks the uncared-for eyes of newborn infants, is often followed by opacity, and is the usual cause of the condition which is erroneously described as being "born blind". There are no blood-vessels in the cornea, of course, and it is nourished by lymph exuded from the walls of the capillaries which skirt it in the sclerotic coat of the eye.

Looking through the cornea we see a ring of color surrounding a circular black hole which is conspicuously variable in size. The black hole *is* a hole, leading into the dark chamber of the eye; but under certain conditions, as when we throw light into the eye by the ophthalmoscope, the dark hole becomes bright, and we see clearly the brilliant red back of the eye, by means of light reflected from it to our eyes. This black hole, or pupil, is surrounded by a muscular structure, called the iris, and the interval between pupil and iris behind, and the cornea in front, is known as the anterior chamber of the eye, and is filled with a transparent watery fluid known as the aqueous humor.

The exquisite graduation by the iris of light entering the eye

The color of the iris is not due to its muscular tissue, for in pink-eyed or albino animals or human beings the natural pink color of the blood in the muscle shows itself, but it is due to the presence

of pigment in certain pigment cells, upon the back of the iris in all but albinos, and upon the back and the front of the iris in brown, hazel and green eyes. The inheritance of the pigment upon the front of the iris — in the absence of which the eye is blue or clear grey — has lately been shown to follow the law of Mendel.

The iris is opaque, so that no light enters deeper into the eye except such as passes through the pupil. This quantity is exquisitely graduated by the iris, under the delicate nervous control of certain subordinate centers which are in connection with the retina, and so can signal to the iris according to the quantity of light which is falling upon the retina. Thus if we open the eyes before a mirror in any good light, we at once see the pupils contract, owing to the reflex stimulation of the iris by the light. When the eyes are closed this stimulation ceases, and the pupils dilate. This in itself means rest, of course, for the iris and the nerves which control it. Very few people have the wisdom, however, to appreciate the value of closing the eyes when there is nothing to see, though this simple act rests the whole visual apparatus, from the machinery which raises the upper lids back to the vision-center in the brain itself.

How concentration of light on the retina is secured

If the pupils of a friend be observed when the vision is directed from a distant object, such as a landscape seen through the window, to a near object, such as the glass of the window itself, we observe that the pupils contract in this case also, just as when more light is thrown into the eye. This is a beautiful adaptation for the purposes of clear vision.

The rays of light from a near object diverge so much that it would be impossible for the ocular apparatus to bring the outer rays to a focus upon the retina. Hence the iris contracts and cuts off the outer rays. This means slightly less brilliant illumination, but much clearer definition. It follows, of course, that the iris works harder when we are looking at near objects than for distant vision.

The marked curvature of the cornea and the aqueous humor necessarily compel them to act as lenses upon the rays of light which traverse them. But immediately behind the iris and pupil we find a special structure, an actual lens, which has to be seen to be believed, and which may well have led Darwin to confess that he could never think of the eye without wondering whether natural selection could really account for it. This is a circular, bi-convex, transparent lens, derived from the surface of the body ectoderm, like all the parts which we have hitherto studied (except the muscular tissue of the iris, which has a deeper ectodermal origin), and it constitutes the front wall of the posterior chamber of the eye, which is filled with a semi-solid, glassy material — hence called the vitreous body.

The part played in sight by the crystalline lens

The lens itself consists of a number of fibers, each originally a cell from the outer or ectodermal layer of the skin of the embryo, which has been modified into a peculiar chemical compound called crystallin. This crystalline lens, to give it its full name, tends to lose its notable elasticity in middle life, and hence becomes somewhat flatter and less convex. After its shape and transparency, its elasticity is its most important and remarkable feature, for upon this alone depends the capacity of the eye to afford us clear vision both of near and distant objects. For the lens lies in a capsule which is so connected with a circular muscle, the ciliary muscle of the eye, that when this muscle contracts the pressure upon the lens diminishes and it bulges in virtue of its elasticity. But when the ciliary muscle is not in action the lens is in a condition of considerable pressure, and is therefore flattened, and made much less powerful as an optical instrument.

This means that, so long as the lens retains sufficient elasticity, its shape can be accommodated for near or distant vision. In what is called positive accommodation, for the vision of near objects, the ciliary muscle is thrown into action, the so-called suspensory ligament of the lens

is relaxed, and the lens bulges in virtue of its elasticity, so that the rays of light passing through it (rays which, being from a near object, are diverging) are sharply bent and made to converge so as to form a clear image upon the retina at the back of the eye. But in what is called negative accommodation, the ciliary muscle ceases to act, the suspensory ligament of the lens is tense, the lens is flattened, and nicely adapted (in the fortunate and rare owners of such eyes) to focus the parallel rays of light from distant objects upon the retina.

Hence, as the names imply, it is positive accommodation, for the vision of near objects, that involves strain upon the eye. It means that not only is the iris, as we have seen, thrown into more energetic action, but that the ciliary muscle is at work; hence it is use of the eyes at short distances that is liable to fatigue them.

The focusing of our sight to suit different distances

The human eye is normally focused upon infinity. It is ready to see distant objects without muscular effort. But, by the marvelous apparatus which the nineteenth century asked us to accept as the result of the natural selection of chance variations, the eye is able to alter its optical properties, so that near objects may, on occasion, be accurately focused also. Modern man, however, reverses the proportions of work for which the eye has been evolved. It has been contrived so that positive accommodation, the act which involves strain, shall adapt it to what, in the past, have been occasional and usually little more than momentary purposes, before it returns to the sky, the horizon or the almost passive alertness for the approach of an enemy. Modern man sets this eye to work on a book for hours at a time, and then finds that it tires. We note, however, that Life has by no means finished constructing apparatus to suit its purposes. The prolonged use of the eye at short distances alters the shape of the eyeball as a whole, the constant pull of the ciliary muscle upon its attachments lengthening the eyeball from back to front, so that it becomes better suited for dealing with rays from near objects, and less strain is involved in positive accommodation. Thus we can in considerable measure permanently alter the shape of the eyeball to suit our personal purposes.

The meaning of the technical terms used in diagnosing sight

The technical names for the various conditions of the eye, from the optical point of view, are emmetropia (ęm = eu, or good, as in euphony, eugenics, etc.), where the eye is normal, hypermetropia for long-sightedness, myopia for short-sightedness, and presbyopia for the long-sightedness of advancing age, due to the diminished elasticity of the lens. These various conditions of the eye are of much importance for health, and will be dealt with elsewhere in this work. Their importance, however, is purely mechanical, and they need not further concern us here.

Hitherto we have been discussing nothing but mechanical devices for admitting rays of light, regulating their quantity, and refracting them. We now come to the retina, or curtain, at the back of the eye, on which inverted images of external objects are thrown by the action of the cornea, the lens and the other refracting media of the eye. The retina is essentially a nervous structure. Historically, as we have seen, it is a bulb of the brain, and it is extremely rich in nerve-cells. Anatomists commonly distinguish eight layers in the retina.

The rods and cones or characteristic visual cells of the eye

The foremost layer consists of six-sided cells which are deeply pigmented. Immediately under them we encounter the characteristic visual cells, known from their shape as the rods and cones respectively.

These form a well-marked palisade of cells under the pigmented layer, and they are regarded as modifications of the cells which line the internal cavity of the brain. This we can readily understand if we remember the history of the retina. But these visual cells have been profoundly modified for a special function.

They are not nerve-cells, as indeed their historical origin shows, but they are the cells which are immediately affected by light, and they are in intimate connection with a vast number of nerve-cells and with the terminals of the optic nerve.

Except in one area, the rods are much more numerous than the cones. Each rod has an inner and an outer segment, the latter a cylindrical pile of very thin discs deeply colored with a pigment known as "rhodopsin" or visual purple, which is chemically sensitive to light, and especially to the blue and violet rays, just like the sensitive films used in photography. As shown on page 2634, the cones are different in shape, and their outer segment is practically colorless. At what is called the yellow spot of the retina, near its middle, the cones alone are found, and hence the marked contrast of its color. Both rods and cones are living cells, with nuclei, but these nuclei are found at a considerably deeper level in the retina. There is a marked resemblance, on the whole, between the arrangement and distribution of the nerve-cells in the retina and the nerve-cells in the cortex cerebri — a fact which our historical knowledge of the retina as a projection of the brain itself helps us to understand.

The blind spot where the optic nerve enters the eye

About one-tenth of an inch towards the inner side of the eye from the yellow spot, the optic nerve enters the eye. Here the retinal elements themselves are absent, and hence this spot is blind. The presence of this optic disc or blind spot in the eye can readily be demonstrated by means of this diagram.

X ●

If we close one eye, say the left, and look at the cross with the right, at a certain distance the dot will be invisible, though when we move the page nearer, or further, it comes into view again. At the distance at which it disappears, the rays from it fall on the blind spot, provided that the eye be fixed on the cross, so that the rays from it fall upon the yellow spot of the eye.

Though the rods are highly specialized, and though their pigment is rapidly changed, by the action of light, first into yellow, and then into white, yet it is believed that the capacities of the rods are limited, and that they do not serve to distinguish between colors. Much higher in development, and later in the evolutionary record leading up to man, are the cones and their concentration in the yellow spot. At this spot it is evident that everything is uniquely favorable to acute vision. Here the retina is exceedingly thin, not laden with supporting fibers, nor with blood-vessels of any size. When we look at near objects the two eyes slightly converge, so that the rays received by both eyes may fall upon the yellow spot of each retina.

What optical experiment shows of the action of the rods and cones

Careful optical experiment has proved that the cones, and no other level of the retina in this area, are the visual terminals; and it has been found that in visual fatigue the chromatin of the nuclei of the cones tends to disappear. It has further been shown that two objects, such as the points of a pair of compasses, which can be seen as two so long as the rays from them impinge upon the yellow spot, can only be seen as one when the rays strike upon any other part of the retina. Two objects so near together — for instance, as double stars — as to affect only one cone, only afford one image. In order to get two images, two cones must be involved; and the reason why the compass-points are seen as double by the yellow spot, but not by any other part of the retina, is that in other parts the cones lie further apart, being diluted, so to speak, by the rods.

Much attention has lately been devoted by psychologists to the special functions of the rods and cones respectively. They have observed that colors are not distinguished appreciably by the outermost parts of the retina, and that there the cones are very few. They have noticed, also, how the yellow spot and the cones are found only in the very highest type of eyes; and careful experiment has led to the conclusions thus summarized by Dr. McDougall:

The rods the means of sight in a dim light

"The function of the rods is to enable us to see in light so dim that it cannot stimulate the cones. We may regard the rods as representing a primitive form of visual sense-organ from which the cones have become differentiated and specialized. In ordinary daylight our visual sensations are excited through the cones only, for the rods are kept in a state of exhaustion by so bright light. [We saw how light bleaches the visual purple of the rods.] But when the eyes have been shielded from bright light for some minutes, the rods regain their sensitivity. Hence on entering a dimly lit room, or on going out of doors from a brightly lit room on a moonless but starlit night, we can at first see little or nothing, for the cones are insensitive to so dim a light, and the rods are exhausted. After a few minutes, the rods having regained their sensitivity, we can see the outlines of objects, and differences of light and shade, but no colors for the rods mediate only one quality of sensation — a slightly bluish-gray, of small range of intensity.

"If, then, one looks at a small object, such as one of the dimmer stars, it will be found to become invisible as the eye is turned directly upon it, for its image then falls upon the central region of the retina in which no rods are present. Since the rods mediate a single elementary sensation-quality, no matter what be the kind of light falling upon them, and since they are sensitive to light too dim to affect the cones, the solar spectrum, when made of very low intensity, appears no longer as a band of colors, but as a band of dim gray light a little shortened at the red end. The shortening at the red end is due to the fact that, while the rods are sensitive to rays of all other parts of the spectrum, they are insensitive to the red rays or rays of greatest wave-length.

"It has recently been shown, also, that the rods respond to stimulation less rapidly than the cones, so that the sensations resulting from the stimulation of them appear in consciousness an appreciable interval after those due to simultaneous stimulation of the cones."

The cones responsible for sight in bright light and for discrimination of color

These facts are extraordinarily interesting. The older type of organ, the rod, is *more* sensitive, we observe, in mere terms of quantity. It will respond when the cones show us nothing, so that a faint star, seen slightly askance, disappears when we look straight at it and its light falls on cones only. On the most obvious and commonly accepted criterion of sensibility, the rods are thus of a higher order than the cones. But this case teaches us what is abundantly true in the analogous case of the ear — that the true measure of sensibility is not quantitative but qualitative. The rods may be able to see where the cones cannot, but all colors are one to them, and they have nothing like the same powers of discrimination, apart altogether from color, that the cones have. It becomes an interesting question for general, as distinguished from human, psychology to decide whether the qualities of color sensation are appreciated at all by those creatures in whose eyes the cones and the yellow spot are not to be found. And we are also entitled to argue, from the size of the yellow spot in ourselves, and from the quite astonishingly large area of the cortex cerebri which is associated with vision, that in man the development of this sense is preëminent, even though he may be neither hawk-eyed nor lynx-eyed.

Color-blindness seldom due to defect in cones

When we learn that the cones are responsible for our discrimination of colors, we seem to have in our hands the key to color-blindness, which we might expect to be due to defect of the cones. That is true of the very rare cases of complete color-blindness, in which it is found that the retina is blind where the rods are absent, which means that the cones, though present, cannot perform their functions at all. But in other cases of color-blindness the peculiarity is more subtle. The cones are present and perform their functions, but certain definite defects exist in the individual's color-vision.

These defects have now been shown in many instances to obey the Mendelian law of transmission by heredity; and this suggests that, as in many other cases of Mendelian transmission, the factor at work is chemical. Further, cases of partial color-blindness, such as are met with every day, usually depend upon the lack of capacity to see certain particular colors, such as red or blue.

Dr. Young's theory of color-vision in combinations

Evidence of this kind affords a theory of color vision which has several variants, but is essentially one and the same in all cases. This is the theory, first suggested by Dr. Thomas Young, the founder of the wave-theory of light, that our visual apparatus contains a few units — whatever they may be — three or four in number, each of which is capable of appreciating a particular color, and that our appreciation of all the infinite varieties of color is due to varying blends of these few. According to Young, red, green and blue are the primary colors, for each of which our eyes have a special apparatus; and all other qualities of color-sensation, including white, are fusions of these three elementary qualities, or of two of them. To these three, as defined by Young about a century ago, we must now add the special grayish "color", if so it can be called, which is peculiar to the function of the rods; and we seem therefore compelled to believe that in the visual area of the cortex cerebri there must be four distinct substances, or sets of substances, each concerned in the production of one of these four primary elements. Color-blindness thus becomes intelligible in chemical terms, as due to the defect of one or other of these substances; and we can dimly imagine how such a chemical peculiarity, like many others, may be capable of Mendelian transmission in heredity.

Innumerable optical problems are raised in the discussion of the mechanics of vision, as, for instance, in the muscular apparatus by which the two eyeballs are moved together. These are very important for the oculist who has to deal with a squint, for instance, but they matter little to the student of man as a whole.

The visual memory in people who have become blind

Much more to our purpose is the final question as to the seat of visual memory, and of the various processes of visual recognition, the combination of sensations to make a whole which we call perception — the process illustrated in "puzzle-pictures" — and the recall of visual perceptions and construction of new ones by the "inward eye". On this point the evidence is clear. Visual images cannot be called up by those born blind, or those who have lost their sight at as early an age as two years. But if vision has been enjoyed in the ordinary way, and then the eyes lose their functions, or are even removed by the surgeon, clear and distinct visual images may still be seen by the outwardly blind man. This is conclusive proof that the eye is not the essential factor in this process, though the past functioning of the eye is necessary. But if the visual area of the brain be destroyed or thrown out of action, no visual images will be formed. Hence we know for certain that it is the visual area of the brain which remembers, recalls and creates. But what is the full significance of those three verbs we cannot realize until our psychological studies have gone deeper.

The glories of the inward eye lit by memory and thought

Meanwhile, we see that the eye is merely machinery for transmission, and that both vision and the memory of vision, leading even to the artist's and the prophet's conceptions, are achievements of the brain alone. A Homer or a Milton may lose the functions of what we call their eyes, and become blind. But the inward eye remains. If it has been made "a mansion for all lovely forms", it can still see beyond the darkness of the present and the grave. Such blind men are seers still.

THE DEMAND FOR ALCOHOL

The Difference between Thirst and a Craving;
and the Vicious Circle Set up by Poisons

KEEPING A BALANCE IN NATURE'S BANK

THE influence upon the body of a substance with such various and marked physical and chemical properties as alcohol is, of course, equally various and marked. To study it as completely as our present knowledge permits would be matter for a treatise. But our treatment of it can be simplified by reference to some general principles as to the demand for alcohol; and the most important of these depends upon the nature of thirst.

This is a subject we have already discussed. We have seen that all life is lived in water, that the processes of life inevitably tend to foul this water, that life will therefore poison itself if the water be stagnant, and that thus every living creature requires to have an unceasing stream of water running through its person. Thirst is thus a constant attribute of all living creatures, microbes, mice and men. This is the proper and original use of the word, but we may extend it as we please, by analogy, to speak of a thirst for music, or, if we will, a smoker's thirst for his after-breakfast smoke. But here we mean a crave, a need, an appetite, a want, a liking; and these may be normal or abnormal, healthy or vicious, but are certainly not the primary need that water is.

And we are to observe that nothing will take the place of water. This is a definite chemical compound, which the body must have. Food will not replace it, nor drugs, nor alcohol. The desire for alcohol may be called a thirst, if the desire for anything liquid is a thirst, but the term as used is grossly misleading, and does mislead nearly everyone.

The fact is that the normal, regular vital thirst for water and the liking for alcohol are usually confounded — none the less readily because, in many instances, the two are gratified together, in varying proportions. The thirsty golfer drinking a light beer is chiefly desirous of water to replace what he lost when his muscles and skin were working; and the fact that alcohol is in the beer is not what interests him. He would not turn up his nose at tea or lemonade or half a dozen oranges, or even a glass of water. He is really thirsty. That same man, in his club, after a day's sedentary work, and again ordering a glass of beer, may now be desiring not the water it contains, as he did the other day, but the alcohol. The same man drinks the same fluid, but the two cases are quite different physiologically, and they lead to quite different ends.

Now, morbid introspection and hypochondria and pulse-counting are by no means to be confounded with intelligent understanding of oneself, by which every man, not a fool, should become his own best physician at forty. And, among other things, it is well to know why one really does or desires things. Thus, to describe what may perhaps be a morbid craving, six months more of which will kill one, as "thirst" is simply an incitement to suicide. Most sensible people will therefore be grateful for a simple, safe, absolutely reliable test of thirst, to which, somewhat anticipating, we may add a parallel test for hunger.

As regards the latter, there may be exceptions in certain kinds of invalidism, but, apart from these, we may say that a man is hungry when he gladly eats dry

bread. This answers to the general conception of hunger as desire for *food* — food pure and simple. We offer the tramp who says he is hungry, or the greedy child at table, a piece of bread, which is food, pure and simple, and the test is a sure one. If he wants taste, flavor, stimulation, but is not hungry, he will, in effect, say of the food you offer him: "Thank you for nothing." This test, as we shall later see, may be applied, on occasion, not merely to tramps and children, but even to our noble selves (who, in fact, are rarely really hungry), and with surprising results.

The desire to drink water the true test of thirst

Now let us apply this idea to thirst. If hunger is desire for food, a hungry person will accept food. If thirst is desire for water, a thirsty person will accept water. In the case of hunger, we noted an exception, for ill people may need food, and even enjoy food, but the sense of hunger is itself ill in them, and such that, as we say, their appetite requires to be tempted. The explanation of this may be that the secretions of the mouth and stomach, necessary to moisten the food and swallow it — secretions which are quickly produced by dry bread in healthy hunger — require some further inducement in the ill person, who therefore cannot eat what is quite nice enough for us. If it left our mouths dry also, we should reject it also.

There is no parallel to this in the case of thirst, for water requires no moistening in order to get it swallowed, nor any digestion. Hence the rule is absolute and without exception that the person who — not being too weak to open the mouth — refuses pure water is *not thirsty*. We may feel something that corresponds to thirst, which may be a subordinate element in it, but if it rejects water it is not.

A man may call and fancy himself thirsty because he "wants a drink" at eleven in the morning, and may drink freely (if he can get it) at a carouse at night, but that was not thirst in either case. Next morning, however, as he consumes pitcher after pitcher of water, and the very thought of whisky makes him sick, he will call himself thirsty also, and at last he will be right. In fact, this real thirst which follows the taking of alcohol is a question the answer to which provides us with the key to many features of the action of alcohol on the body.

Ask the chemist what are the relations of alcohol to water, and he replies that, in the proper sense of the word, alcohol is almost the thirstiest thing he knows. Sulphuric acid and some other substances are to be grouped with it in this connection, on account of their remarkable affinity for water. If pure sulphuric acid or absolute alcohol be exposed to water, such as is contained in an ordinary atmosphere, they instantly dilute themselves with it. The process is more than dilution, and has some of the properties of chemical union, so urgent is the affinity. We speak of "absolute alcohol", but so intense is the thirst of this substance that probably chemistry will never be able to extract the last molecule of water from a portion of alcohol so that it shall be really absolute; and what we call absolute alcohol may be 98 or 99 per cent of alcohol, and the rest irremovable water.

The affinity of alcohol for water a fundamental cause of thirst

This affinity of alcohol for water is the most important and marked of its physical properties. Hence, if absolute alcohol be applied to a living tissue (say, of the skin or the mouth), which is, of course, mostly composed of water, the alcohol violently abstracts the water in order to satisfy its own thirst, and the result is immediately destructive to the tissue, which has thus been dehydrated, as we say. Alcohol may thus be used, on occasion, as a caustic, but no one can bear to take it in such concentration. This is the key to the "burning taste", and sensation in the stomach, aroused by strong alcoholic solutions. They are simply diluting themselves at the expense of the first tissues which they encounter. Thereafter, the alcohol, somewhat diluted, fortunately, but by no means sufficiently so, enters the blood.

The insistent demand of the blood for water

The blood is a complex thing, with living elements, but meanwhile we are to look merely at its fluid part. The most remarkable fact about the fluid of the blood is its astonishing degree of constancy of composition. It is forever supplying certain of its ingredients to the tissues, and forever receiving other ingredients from them, and from the bowel, but it has almost an infinity of devices for always returning to a certain normal composition, in whatever direction that may be disturbed. This applies not least to the mere proportion of water in the blood, and thus to its actual physical bulk. If much fluid passes into the blood, much fluid is quickly expelled from it, as anyone may observe. If there is a failure of fluid supply from without, the blood will abstract water from the tissues and the bowel, rather than go short — its bulk and proportion of water must be maintained at all costs, for otherwise the brain would have to suffer.

Now, consider the consequences of the introduction of a foreign substance like alcohol into the blood. Of course, it must be got rid of, and as it goes it drags a quantity of water along with it. The result is that the blood is left thirsty.

The abstraction from the body by alcohol of the water needed by the blood

The alcohol that goes out by way of the skin increases the activity of the sweat glands, especially if the drinking is accompanied by surface warmth, and thus causes an increased loss of water. That which leaves by way of the kidneys has a similar action upon those organs, particularly under the opposite condition of cold. In either case, the loss of water leads to thirst to restore the balance.

Further, as we have seen, some of the alcohol is oxidized, yielding new products. If these were carbonic acid and water, plainly thirst would not result; and the fact that thirst does result supports the contention that the oxidation of alcohol in the body is not complete and therefore harmless or useful, but is like the oxidation of many other drugs, such as morphine, yielding new substances which are essentially toxic. Thus we now have two explanations, between them quite adequate, for the very remarkable thirst which follows the slaking of what the drinker wrongly calls his thirst. First, it is due to the action of alcohol in causing the body to lose water, with which it requires to be replenished as soon as possible; and second, it is due to the production of poisonous substances in the body, perhaps from the alcohol itself, which the body seeks to render harmless by diluting them as far as possible, as in the case of the thirst of fever, and of all forms of intoxication, whether by drugs or microbes, or exertion or otherwise.

Alcohol a mocker, causing afresh the thirst it seems to allay

This, then, is the first one we have encountered of the many instances in which alcohol, in the biblical phrase, is a "mocker". It looks like something that relieves thirst, something that tastes wet and will so allay what feels like thirst: but so far is it from doing so that, on the contrary, it sets up the conditions that cause thirst by depriving the body of the one thing which does relieve it, and the loss of which produces thirst — namely, water. From the point of view of the student of physiological chemistry, there is an almost diabolical cunning in the ease and constancy with which poor human nature is thus cheated. For, unless the alcohol be very dilute, every successive drink only increases (after a little while, when the mouth and throat get dry again) the thirst which it is supposed to relieve, and thus a vicious circle is set up, to which the subtler action of the alcohol itself upon nervous protoplasm contributes.

Surely it must be a contribution to public health that we should call things by their real names, and that we should thus try to rid ourselves of the tyranny of imitations; for the imitations of thirst, the imitations of patriotism, the imitations of religion, are at all times very nearly too much for the life of man.

The desire for alcohol not a need of the body, but an unnatural craving

We see now that the desire for alcohol is really a craving, an acquired demand of the body. This is the essential and material reason why men drink it. They do also drink alcoholic liquors, as we have seen, in order to relieve thirst, and we have seen what a different aspect that intention wears according to the alcoholic strength of the liquid; secondly, they sometimes drink for the bouquet of the beverage, for the pleasure of the nose and palate; but thirdly, they drink to satisfy a crave, which they commonly misname as thirst — though the inebriate who is glad to get at methylated spirits is under no delusion as to the nature of his case. If we are to understand the relation of alcohol to personal hygiene, on the individual or the national scale, we must therefore try to understand what a crave really is from the physiological standpoint.

We do well to distinguish craves from needs. The body needs light, air, food, water, and does not acquire the desire for them. Though we habitually avail ourselves of these things, their use is not to be called a habit, nor yet the desire for them a crave. Again, we acquire the habit of liking certain things, particular flavors in our diet, books, music, company and so forth, and these are properly to be called habits. The essence of them is that they are acquired, though they may doubtless spring from native tendencies. Habits may be bad as well as good — for instance, the habit of swearing, or making grimaces when one talks, or biting one's nails. The discussion of such habits, good and bad, is very interesting for the psychologist, but what we are here discussing is something quite different in its nature, though our use of language is so careless, that we often speak of obviously immoderate drinking as "a bad habit". But all this is subordinate and essentially beside the mark. The so-called "habits", bad or not as they may be, of drinking, or smoking, or taking any other drug, are of a wholly distinct nature from other habits properly so called.

The difference between a habit and a craving caused by drugs

A real habit is a nervous thing; it means that, as we do our best to imagine it, a kind of rut or easy path has been worn in one's nervous system, so that action tends to discharge itself along it, and so becomes habitual. This is a thing acquired with astonishing speed, especially in youth, and, in most cases, discarded or altered with no less speed. When we deal with real habits, not expressions of unalterable instinct, nor drug-cravings, we soon discover how much the so-called "force of habit" has been overrated, and that such true habits, though they have the standing of a life-time, can in most instances be unlearned, and others substituted for them, within a few days or weeks, especially if one takes certain precautions, or necessity imposes suitable conditions upon us.

But that is because, of course, true habit is not a native and permanent and necessary thing, but a mere adaptation or acquirement; and the faculty of making such acquirements was not exhausted when that habit was acquired, and can now show itself by unacquiring it, or acquiring its opposite. These assertions will appear to break down at once, whenever what is not really a habit, or "acquired automatism", is mistaken for one.

The case is wholly changed when we study such so-called habits as the desire for any drugs — alcohol, opium, cocaine, trional, nicotine, or whatever others, familiar, or yet to be constructed in the laboratories, we care to imagine. Here we have something which, though doubtless showing itself through the nerves, is not nervous, like a grimace or trick of speech, but chemical. Just in proportion as it can be shown to depend *not* on habit, but on certain chemical facts which, by their nature, are beyond the control of the individual — as a true habit normally is *not* — do we come to see that calling the drink crave a "bad habit" is both inaccurate and unjust, and will certainly lead us to adopt useless instead of useful courses in dealing with the drinker.

The treatment of patients who have fallen under the power of a craving

It is not only to the question of alcohol that our present discussion applies. It is a matter which directly affects every individual and the nation at large in their relation to any drug habit, so-called. If the thing is really a bad habit, neither more nor less, then we should punish it — the person is a criminal. But if it is a chemical necessity, in the chains of which he has bound himself, then he is a patient, and must not be punished, but treated.

The fact is familiar to first-hand students of the inebriate that there are different types of drinkers. There is undoubtedly the vicious drinker; and here we may briefly recognize him, and then put him aside, as he concerns us no further. He is usually of strong constitution, often exceptionally so. Certain of the psychological effects of alcohol please him, and so he drinks. He may have no true crave whatever. He could control himself if he would, but he will not. Observe this description of his psychology; it is what the law, the sum and symbol of our collective wisdom or folly, assumes for every inebriate — that he could control himself if he would, but will not. That is true of the vicious drinker, who is commonly selfish, though he may by no means be physically brutal. On the whole, he does himself singularly little harm, partly because he often is strong to start with and partly because he has and exercises enough self-control to stop short of destroying himself. This is the type at which prohibition especially aims and, can it be made effective, hits — when "private stocks" are exhausted.

The vicious drinker guilty of a cruel criminality

He is, of course, a curse to those with whom he lives, especially women and children; if anyone is a criminal, and should be punished by the law, he is the man. In most countries, the law on this subject is abominably inadequate — lenient to the selfish drunkard, mercilessly cruel to those whom his habit injures. For this is a bad habit, and should be treated and regarded as such. Pity, sympathy, medical skill, all forms of noble things, love and knowledge, are wasted on such a person. What he needs is punishment, and punishment of a harsher kind than public opinion of the present day, which is so pitiless to his children, would tolerate. Probably the number of such cases, relatively to the whole of drunkenness, is quite small.

The scientific view of patients who have contracted the drink craving

If we are to understand the greater part of the problem, we must consider the case of the ordinary person, neither a selfish brute on the one hand, nor a pitiable defective on the other hand, who falls a victim to the drink crave.

Let the abstainer by no means sneer at the danger, even to himself, of acquiring such. Just let him dislocate his shoulder when motoring, and have an opiate every night for a week in order to soothe his pain and give him sleep, and then observe how he enjoys having no opiate on the eighth night. A crave is a chemical condition of the blood, the essential characteristic of which is that it can most completely and quickly be altered — to the relief of the patient — by a further dose of the same chemical substance which produced it. Modern study has thrown much light upon this subject, and has gone far to justify and illustrate the maxim that to know all is to pardon all. The writer must not be understood to assert that what he is about to describe has yet been proved for alcohol, but it has every probability. It has apparently been proved for morphine by Professor Binz, of Bonn.

Briefly, the reader may be reminded that very many instances occur in the botanical world of vegetable products, with powerful actions on the animal body, which can be readily altered, by the plant itself, or otherwise, so as to produce another drug which has opposite actions. In hosts of plants such physiological antagonists can be found in varying proportions. The fact goes far to help us in understanding the action of, for instance, such a vegetable product as morphine.

The patient a victim of a circle of poisonous effects

What happens appears to be that the drug is changed in the body, as a result of oxidation which destroys it as such, so that a new drug is produced, the action of which is also poisonous, but poisonous in the opposite direction. Nothing can serve so well for its antidote as a further dose of the original drug. But that further dose undergoes the same change, and thus the patient is liable to become the victim of a vicious chemical circle, where every dose that relieves his symptoms will surely lead to their production anew.

To the self-righteous or uninstructed it may appear that the foregoing is too clever by half, and may be gaily dismissed. But such people would know better if they had seen a victim of the craving for opium killed outright in a few days by having his drug not stopped, but rashly and excessively reduced. In such cases the patient dies of palpable poisoning, although nothing but good, simple food and water may be entering his body; and a large dose of opium will remove the toxic symptoms just as diphtheria antitoxin will relieve the symptoms produced by the diphtheria toxin. And yet all these symptoms were due to opium. It is a great step forward to have reached an intelligible explanation of the facts. The patient in such cases does not suffer from a lack of anything necessary for life. His symptoms are not those of starvation, as if the opium had become necessary for his nourishment, and he was dying for the lack of it. They are the positive symptoms of an active toxic process; and there is no doubt that those same symptoms would be produced, in degree, in a second person, if he were injected with a small quantity of the blood of the first.

The terrible condition of drug-poisoned people when deprived of their drug

This conception of the nature of a drug crave, as being the outward expression of a vicious chemical circle within the body, may be taken, whatever the details of special instances may prove to be, as fairly typical of drug craves in general, whether common or rare, serious or trifling. It is probably true alike of morphine, alcohol and nicotine, for instance, though the intensity of the action in these instances varies within considerable limits. The opium-smoker or the morphinomaniac, deprived of his pipe or his needle, may forthwith die of acute poisoning, which can scarcely be called opium poisoning, as opium would have prevented it.

The tobacco-smoker, deprived of his weed, may show nervous symptoms of some considerable degree, including irritability, irregular pulse and incapacity to control the attention, but actual delirium will scarcely ensue. The drunkard, similarly deprived, will have a terrible time, and under certain conditions may be precipitated into actual delirium tremens. In all these cases the conception is illustrated that a crave is a chemical poisoning which demands specific chemical relief.

The man who needs alcohol to make him fit is already poisoned

We now have the key to the familiar argument of the smoker, and the still more familiar argument of the drinker. "What nonsense it is", he says, "for fanatics to spout all their rubbish about alcohol (or tobacco) being a poison, when I know, and millions like me know, from the everyday experience of years, that this so-called poison does me good, soothes me or stimulates me, or both at once, helps all my functions and my work, my digestion and appetite, my temper, my sleep, and everything else! My case, like an infinite number besides, proves that this is not a poison, but a valuable aid to life."

This often-heard argument is now intelligible to us. It is quite true, absolutely honest, and we have no difficulty in understanding the very natural irritation of the man whose habitual drink is forbidden him, and who finds his best friend called a poison. But place him in line with the morphinomaniac, and he will observe that, by his argument, morphine is not a poison either — "which is absurd".

The fallacy of his argument has now received chemical elucidation. The non-drinker has an effective reply: "My dear sir, I quite realize that you need your drug. The fact is that you are a patient, and, being so, require constant medication —rather a pitiable necessity, but there it is. I am sure that you have never been drunk in your life, but the truth is that you are a victim of chronic intoxication — by the decomposition products of your last dose of medicine. I quite understand that you need a new dose, and that without it your intoxication — pray pardon me — puts you in a condition of depression, irritability, lack of appetite, inability to concentrate, sleeplessness and feeble digestion, so that you require a drug in order to reach the level of health which, I confess, I am fortunate enough to enjoy without such assistance."

The price paid for submission to poisoning only known at the end

That is surely a fair retort, but the habitual drinker need not give in yet. It is open to him to reply that, after all, he has attained a balance, that he has effected a special adaptation; and though he cannot deny that he has made for himself a requirement which the non-drinker does not share, still that requirement can be easily and completely met.

This argument raises the whole problem of adaptation and its costs. The lover of fresh air gets a bad headache in a stuffy room, where people who are accustomed to foul air, and prefer it, are unharmed. It looks as if they, with what is surely a bad practice, have the merry laugh on him whose healthy preference gives him a headache.

The answer of modern physiology appears to be that, in all such cases, we must look to the end thereof. Prolonged inquiry suggests that in the long run the normal habit and mode of life pay best, because they cost least. The body adapts itself, but it pays a price. It learns to survive under the new and peculiar conditions, for which it was not constructed, but it pays a price, either in the average intensity and efficiency of life, or in the actual length of life, or, as usually happens, in both. Nowhere is better illustrated the everlasting maxim of wisdom — look to the end thereof.

But it is to be granted that the argument requires proper statement and careful inquiry. Immediate observation does not justify it. The drinker or the smoker can not only prove in his own person, day by day, that he is the better for each individual dose of his drug, and is therefore, as would seem, entitled to argue that it is a beneficent drug — forgetting the morphinomaniac, killed for lack of his morphia — but also he can prove, by experiment on himself, that the good results promised if he will stop his "bad habits" do not follow. In point of fact, he feels much worse. This is first-hand evidence; it continues for days, perhaps, and not unnaturally he returns to his pipe or his glass. And even if the renouncer sticks to his guns until the chemical balance of his body has returned to the normal — for no one can deny that not to crave for pipe or glass must be the normal — it is very likely that, while he feels none the worse, he feels none the better.

The statistics of disease a better guide than personal feeling

By no means is this true in every case; the writer has had many scores of letters from those who have followed his advice about alcohol as a public physician, and who proclaim themselves new men or women. But there are probably as many cases, or more, where the self-reformer, not unnaturally proud of his feat, and expecting some return for what it cost him, finds that he is much as he was. Then why on earth, if he is no better, should he not return to what, he argues, clearly does him no harm, and was certainly enjoyable, when looked at from one side? The answer to this frequently encountered and entirely reasonable argument of the individual is that furnished by the statistics of such diseases as cancer and consumption, and by the records of life-insurance companies over now many decades in both the United States and Canada, and elsewhere.

The power of resisting disease limited by the use of alcohol

It is the answer which has been already stated: that the adaptation to any abnormal mode of life costs something, and that this cost shows itself in a shortening of life, and in a marked lowering of its intensity, efficiency and happiness, after a time.

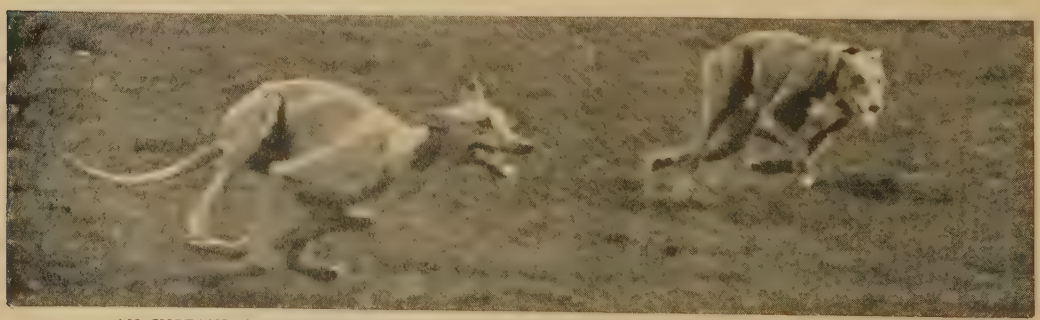
It will be obvious that nothing else can be expected if we consider what the chemical adaptations and reactions to morphine, alcohol, or what not, must cost the body; and evidently the state of health that can be attained by these means under these conditions must be a precarious, difficult and unstable affair, with little margin compared with the health of a person who does not require his body to perform these special chemical feats. And so we should expect to find — what we do so constantly find — that when the body is attacked by a new enemy — influenza, consumption, pneumonia or what not — its balance is far more easily upset, and its resistance far less powerful and rapid, its resources far more limited, in the man who has habitually been plunging so deeply into his physiological resources than in the man who has not. Perhaps both men were healthy, but they kept a very different balance at the bank.

One further point remains for insistence, in regard to what we have learned as to the general relations between alcohol and the body, before we begin to study its local action. This is that, henceforth, our attitude towards any drinker who is in difficulties of any kind in consequence of his drug must be made far more sympathetic, far less censorious than hitherto. Not merely the feeble-minded inebriate, who is another class apart, and does not concern us in this section, as he is beyond the resources of hygiene, but also the ordinary drinker whose practice is injuring him in any way, financially, socially, physiologically, requires to be looked upon as a doctor looks upon a patient for whom he has been too freely prescribing an opiate that must now be controlled.

The difficulty of tiding the drinker over changes in his bodily chemistry

The problem before us is not vice, though it may have vicious connections and consequences, or even a vicious or foolish origin; it is chemistry. Let us use all resources available in the way of advice, but let us moderate our blaming, and, having begun to understand, let us go on to treat with understanding. If the drinker is to be deprived of what he has come to need, in the singular boomerang-like fashion we have discussed, we must do our best to replace that need with something harmless. To deprive him of his drug and leave him depressed, uncompanioned, with no interest, no tonic, no suitable diet for his feeble digestion, nothing but nagging or ostentatious approval, no attempt to counteract his toxic state and tide him over the critical change in his bodily chemistry — this is to court failure. But it is the almost universal practice, and will continue to be so until the public receives a little elementary education in the matters which most concern its health and happiness.

THE SUN AS AN ARTIST



AN INSTANTANEOUS PHOTOGRAPH OF TWO GREYHOUNDS RACING AT FULL SPEED

THE SUN AS AN ARTIST

The Wonderful Powers of Vision That
Have Been Derived from the Camera

THE ADVANCE IN THE ART OF PHOTOGRAPHY

IN science the fact that seems most trivial often proves of vast importance. Euclid observed that when a small hole in a darkened room allowed the light in the street outside to enter, a picture of what was going on in the street was visible on the back wall of the room. This is the principle of the camera obscura, still found in many popular resorts. Roger Bacon, in his "Perspective", written about 1267, describes an apparatus with a mirror, by means of which it was possible to see what is going on in the street, so that "those looking will run to the image and think the things are there, when there is nothing but a mere reflection". But the first practical use of the camera obscura was apparently made in 1568 by Daniello Barbaro, a Venetian artist. In his work on perspective he gives the following elaborate instructions:

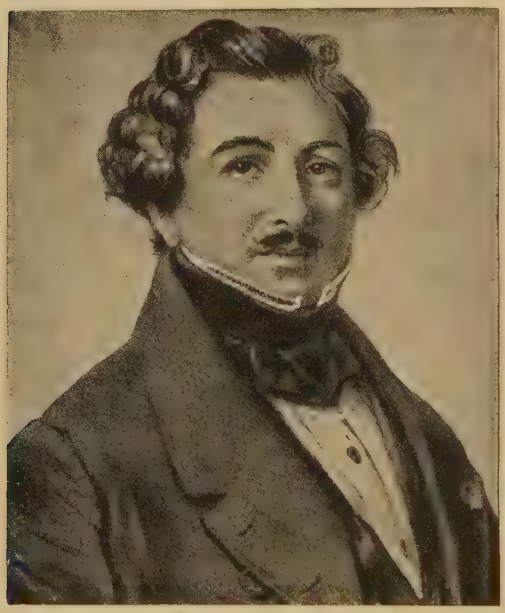
"Make a hole in the window-shutter of a room, and fit into this hole one of the spectacle-glasses that aged men use. Shut all the doors and windows, so that no light may enter the room, except through the spectacle-glass. Take a sheet of paper, and bring it gradually in front of the glass until you find the proper position. Then you will perceive on the paper the image of the things as they are, the gradations, colors, shadows, movements, the clouds, the rippling of water, birds flying and every visible thing. If you cover the glass so that you leave only a little hole in the middle, you will get a brighter effect. And, seeing on the paper, the outlines of things, you can draw all the perspective with a pencil, and put in the shading and coloring according to nature."

Made in portable form this kind of instrument was used by many amateur artists in the eighteenth century which led quite naturally to the desire to fix the images projected through the lens in permanent form by chemical action, and in fact was the inspiration which led to the discovery of photography.

Historians do not agree as to who was the actual father of photography. The Germans claim Schultze, the French Niepce, the English Wedgwood and Davy. The Schultze claim dates back to 1727, and is based on the fact that he actually obtained copies of writing on surfaces of chalk and silver nitrate. Silver nitrate, however, was known as early as the eighth century, and the alchemists of the sixteenth century in their search for a means of transmuting baser metals to gold, had observed the sensitiveness to light of various silver compounds.

In 1802 Wedgwood sought to find a short cut to silhouette-making — then a popular form of portraiture — by printing the profiles of sitters on a surface prepared with silver nitrate, thus following the Schultze clue of the sensitiveness of this chemical substance. In 1813 Joseph Nicéphore Niepce (1765–1833) began working at a process based on earlier discoveries of the light-sensitive properties of certain resinous gums, and after a long series of experiments he succeeded, about 1824, in obtaining a light-sensitive medium composed of asphaltum, dissolved in a special oil. A film of this solution flowed on plates of metal and dried presented a substance which was so changed by the action of light that it became insoluble in the oil.

On exposing the sensitized plate to light passing through a transparent paper print, the part shielded by the print remained soluble, and when washed away by a solvent, the design showed up on the bare metal. The undissolved film of asphaltum protected the plate sufficiently to permit the bare portions being etched with acid, thus producing an intaglio photo-engraving. A specimen of these early productions on a plate of tin made in 1825 has been preserved in the Niepce Museum at his birthplace — Châlon-sur-Saône, — and is doubtless the oldest result of a photographic process extant.



LOUIS J. M. DAGUERRE

It will be seen that two different principles were involved in these early experiments in photography, — one based on the sensitiveness of silver compounds and the other on the insolubility of certain other compounds when exposed to light. The former is today the fundamental basis of all photographic processes, and the latter is in everyday use in photo-engraving and lithography.

Bearing in mind that the desire for a means of producing a photographic image was to fix the fleeting pictures of the camera obscura, Niepce experimented with his asphaltum film, but found that it was not sufficiently sensitive to be of practical use in the camera. He obtained some pictures by a very prolonged exposure in brilliant sunlight, but they were negative, — the lights of the picture being represented by the dark, undissolved portions of the film. He obtained a reversal of the image by flowing his solution on a silver surface which after development he exposed to the fumes of iodine, which darkened it. The asphaltum, when washed off with alcohol, exposed the unblackened silver surfaces, giving the light portions of the image their proper relative positions. In the course of these experiments Niepce noticed the change produced by light on the iodized silver surface of his plates, and tried them in his camera. By means of prolonged exposure, which, however, was much shorter than was necessary with the asphaltum method, he obtained a visible picture on the silver plate, but it was not permanent. On being viewed in the light, the whole surface was naturally again affected, and the image disappeared. While working to improve his method, Niepce was brought in contact with a Parisian scene painter, Louis J. M. Daguerre (1789–1851), who had been trying to fix the image of the camera obscura with phosphorescent substances. They combined their efforts in a partnership, but two and a half years later, in July, 1833, Niepce died, leaving his son Isadore to carry on his work.

Daguerre kept on, but finally abandoned the asphaltum film in his efforts in some way to utilize the much greater light sensitiveness of the iodized silver. An interesting fact contributed to his ultimate success. He had stocked away a number of plates in a closet in his dark room, on which he had been unable to obtain an image due to insufficient exposure. On taking them out one day he was astonished to find a visible picture on the uppermost plate. Surmising that something in the closet had brought about this effect, he proceeded to remove the contents one after another, — leaving a plate to be worked upon after each removal. Having taken out everything that he could find, and the effect still continuing, Daguerre was at his wit's end, when he discovered in the closet some globules of mercury that had

A FLASHLIGHT PHOTOGRAPH OF SOLDIERS IN BIVOUAC

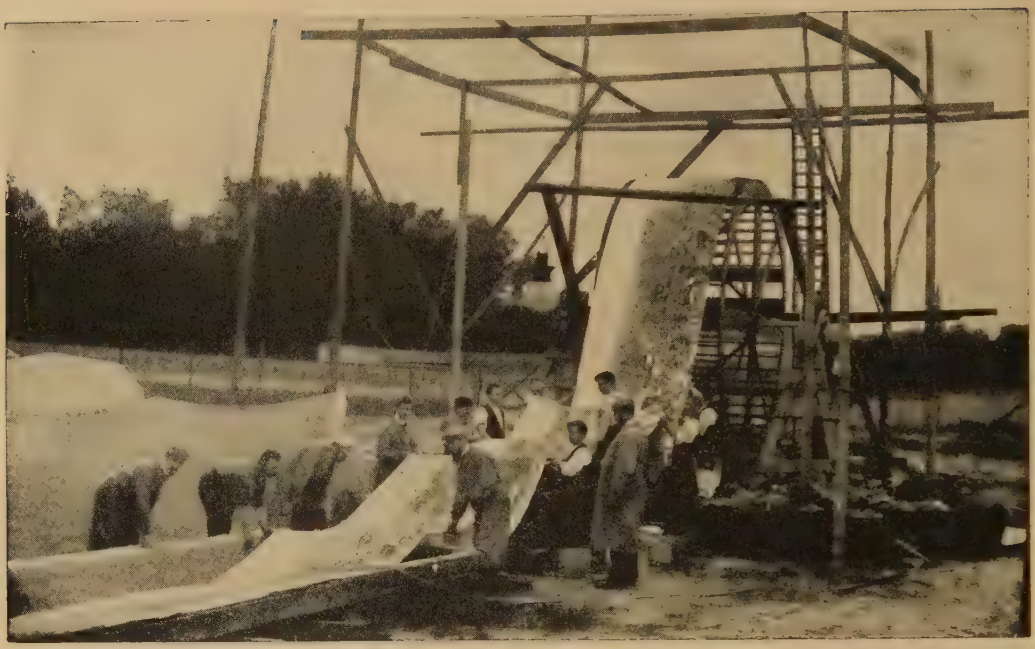
remained unnoticed. Following this clue he succeeded in working out a process which consists essentially in the application of mercury vapor to develop the latent image on the iodized silver plate. The all-important factor in this discovery was the revelation of the existence of the unseen photographic image that could be later chemically developed.

After vain efforts to obtain financial support to exploit his invention, Daguerre and young Niepce offered their discoveries to the French government. The discovery was announced at a session of the Academy of Sciences, January 7, 1839, and through the influence of the Academy, the government was induced to purchase the secret, and gave it to the world. The result of the process was known as a daguerreotype.

Experiments by Wedgwood and Davy in the use of chloride of silver instead of nitrate of silver were successful, but the experiments had little practical value until 1839, when Sir John Herschel recommended the use of sodium hyposulphite to Daguerre. The use of this salt, which today is commonly known as "hypo", really solved the problem of fixing and prevented the unexposed parts of the silver from being affected by exposure to the light necessary to see them.

The fact that the silver solutions on Davy's plates required such long exposures naturally led to a search for means of speeding up the sensitive solution, and this was eventually accomplished by the use of bromine in addition to iodine in combination with the silver salts. The new art became popular even though it was necessary to make a separate exposure for each picture, and daguerreotypists multiplied and plied their trade successfully until 1851, when a collodion process was introduced.

A FLASHLIGHT PHOTOGRAPH OF A LION IN ITS NATIVE HAUNT



THE LARGEST PHOTOGRAPHIC PRINT IN THE WORLD — A PANORAMA OF THE BAY OF NAPLES

W. H. Fox Talbot (1800–1877), an English contemporary of Daguerre, developed a process called calotype, wherein paper was impregnated with silver iodide and shortly before exposure washed over with a mixed solution of silver nitrate and gallic acid. After exposure the image was developed by washing the paper with more gallic acid and silver solution, and warming it before the fire. These operations produced paper negatives, and prints were made from them in much the same way as they are now. Up to this time the sensitive silver compounds were used either on metal plates or on paper, but in 1848 Niepce de St. Victoire, nephew of the first Niepce, worked out a method of using a film of albumen to support the silver compound on glass.

A LONG-FOCUS CAMERA FOR PHOTOGRAPHING A DISTANT PANORAMA

In 1851 Frederick Archer Scott introduced collodion in place of albumen. This collodion, generally known as the "wet-plate" process, superseded all others, and made possible the profession of photography, as we understand it. It required an equipment too cumbersome for popular use. It was necessary to first prepare the glass, to obtain a condition of scrupulous cleanliness, coat it with the collodion and the required iodides and bromides, then dip it in a silver bath carried in a light-tight box, and after all these manipulations, the plate was ready to be placed while still wet in the plate-holder for exposure in the camera. Immediate development was essential, and it will be appreciated that the dark-room equipment, sufficient extra glass to insure a number of exposures, the light-tight silver bath, and other chemicals, made up an outfit which was, to say the least, formidable. Of course, for studio work the cumbersomeness of the apparatus was no drawback, and photography developed rapidly among a handful of devotees.

A TELEPHOTOGRAPH CAMERA STUDY OF RED DEER IN THEIR NATIVE WILDS IN WINTER

2653

THE HABITS OF THE MOST SHY ANIMALS CAN NOW BE RECORDED FROM A MILE AWAY BY THE CAMERA FITTED WITH A TELESCOPIC APPARATUS

In 1878 George Eastman, a clerk in a Rochester (N. Y.) savings bank, learned how to make photographs from a local photographer at a cost of $5 for the lessons; but he was not enthusiastic over the load that had to be carried, nor the labor and pains involved. He chanced, however, to read an article in an English magazine on the possibilities of replacing the wet plate with a gelatine dry plate, and he experimented in his spare time and eventually discovered a coat of gelatine and silver bromide that had all the necessary photographic qualities. His achievement was contemporary with that of the commercial production of dry plates in England.

Although the wet plate was scrapped, so far as the amateur photographer was concerned, by the invention of the dry-plate process, it was in no sense superseded for certain technical purposes. It is used in photo-engraving and photo-lithography almost exclusively today. The dry plate, however, made it possible for the enthusiastic amateur to arm himself with the material for a dozen or more exposures in a very compact set of plate holders, and await his return to his dark room before development was necessary. But even the great strides made possible by the use of the dry plate did not really bring photography within the reach of the amateur, on account of the bulk and weight of the plates to be carried. Professional photographers remained by far the largest users of the new dry plate, and the real solution of the amateur photographer's problem pointed to a flexible, light, unbreakable base which should carry the sensitive silver emulsion.

PRESS PHOTOGRAPHY FROM THE DIZZY HEIGHT OF A CITY SKY-SCRAPER

Research on the part of Mr. Eastman and William H. Walker led to the manufacture of rolled film of coated paper to which the sensitized emulsion had been applied. This paper film, however, had the serious disadvantage that, even though it was greased to make it more transparent, the grain of the paper showed when the print was made. Its use, however, led to the appearance of the first Kodak in 1888.

A simple box camera was loaded with a roll of this paper film, sufficient for a hundred circular pictures, two and a half inches in diameter, and the wagon load of wet-plate paraphernalia was condensed into a little box which the photographer could tuck under his arm. After the hundred exposures were made, however, it was necessary to return the camera to the manufacturers for development and reloading; and in due course it was returned to him loaded for another hundred shots, and with the finished prints from his exposed roll.

The paper film was still unsatisfactory, however, and this led to a search for a transparent flexible film base which could be used for carrying the sensitized emul-

A PHOTOGRAPHIC RECORD OF A HISTORIC EVENT—THE BOMB ATTACK ON THE KING OF SPAIN AT MADRID IN MAY, 1906

sion. Collodion, of course, gave the clue to the solving of the problem, but failure to obtain perfect transparency proved a stumbling block. Rev. Dr. Goodwin was the first to successfully produce a clear, transparent, flexible base and this discovery, combined with Mr. Eastman's research, finally produced the so-called celluloid roll film in 1889. The daylight loading feature was the next important step, realized in 1891. In the system first devised, the spool of sensitive film was contained in a light-proof box with a strip of black

NITRATING COTTON FOR FILM MAKING

The film base is a cellulose nitrate made from cotton. The machine consists of a "perforated basket" rotating inside a vat. The cleansed cotton is fed into the basket and acids let into the vat until it is immersed. After allowing sufficient time for nitrating, the acids are drawn off and the basket rotated at high speed for draining. Motion picture film is five-1000th of an inch thick, Kodak film a little over three-1000th.

cloth attached to each end. Another light-tight box contained the spool on which the film was wound after exposure, the cloth at the ends protecting the film during loading and reloading. This did away with the dark room, and the necessity of sending the camera to the Kodak factory for reloading. All that was now necessary to send was the film for development, but the spools of film with their light-proof boxes were clumsy and inconvenient as compared with modern films and daylight home-developing methods.

The daylight loading cartridge system as we know it now, followed about 1894, and has undergone only one important change since: the modern autographic feature which was added in 1914. The daylight developing features were introduced in 1902 and consisted of a developing machine which was a light-tight box made in two compartments. The film was placed in one and wound into a protecting apron in the other. The film and apron were then rotated in the developing solution. This method was superseded later by the tank system, in which the film with its protecting apron is suspended in the developer.

These interesting historical steps, covering a period of something less than a hundred years, have brought us a process universally employed for pleasure, scientific research and instruction. With a few rolls of film and a compact folding camera, one may make permanent pictorial records of his travels and the events of his daily life. Plates which are sensitive to some colors and not to others are employed for the detection of crime. The erasure of a signature with acid, and the subsequent forgery, is often easily discovered, because although the faint yellow stain of the original signature is invisible to the eye, it will appear strong and dark on a photographic plate insensitive to this color.

The motion-picture industry has been built entirely on the roll film which has made possible the thousand-foot reels of the modern photo-drama. Used with the microscope, the photographic plate gives us permanent records magnified three or four thousand times the size of the original under observation. In astronomy, discoveries of heavenly bodies have been made which no human eye has ever seen. The light from a distant star too weak to even act on the nerve centers of the eye has, by prolonged exposure, made a permanent record on photographic plates. The Roentgen Ray, invisible to the eye, gives the shadowgraph used so extensively in examination of many otherwise opaque bodies, and familiarly known as the X-ray picture. Even the first discoveries of Niepce of the insolubility of certain gums

NATURE'S BEAUTY REVEALED IN COLOR BY PHOTOGRAPHY

A COUNTRY ROAD IN SPRINGTIME AS IT APPEARS ON A PHOTOGRAPHIC PLATE PREPARED BY THE LUMIÈRE PROCESS

FACING PAGE 2656

Photo J. J. Ward

NITRATING SILVER

Weighing bars of silver bullion. (The Kodak people use one-twelfth of all the bar silver produced in the United States.) The bars are dissolved in nitric acid, forming silver nitrate in solution, which is evaporated to the point of crystallization in the large porcelain bowls shown in the middle picture. The porcelain basket at the right contains about 1000 ounces of the large, white crystals of pure silver nitrate removed from the evaporators.

when exposed to light have been utilized to give us the waterproof glues and cements used where an impervious adhesive is required. During the Great War photography even recorded the skill of the aërial machine-gunners. Cameras constructed in the form of machine-guns were aimed and fired at training planes, and the photographic image showed clearly where the shots from service guns would have gone. The photograph showed the target plane in position as related to crossed lines representing the point aimed at.

Modern photography employs a vast array of apparatus, photographic emulsions and chemical formulas. Indeed a photographic studio bears a close resemblance to a well-equipped chemical laboratory. The lens is the most important of the mechanical devices, as by its control of light rays the image is focused to sharp definition in a plane occupied by the plate. It is the refrangibility of the rays that makes focusing possible. Reflected from an object and passed

Courtesy Eastman Kodak Co.

through a lens they are refracted according to the shape of the lens and the nature of

the substance of which it is made. When they emerge they are again refracted by the air and focus at a point known as the "plane of focus", the distance of which back of the lens depends upon that between the lens and the object itself. When the object is far away the plane of focus is closer to the lens, and recedes correspondingly as the object is brought nearer. Lenses are ground with spherical surfaces, and it is an inherent fault in all single lenses that the rays which pass through the central areas come to a focus in a different plane from those which pass through the outer areas. This fault is known as "spherical aberration" and is overcome by the addition of lens glasses of suitable material and surface grinding, which when properly combined tend to focus all rays in one plane. Such a combination is known as a "corrected lens".

Correction for spherical aberration does not overcome the lack of sharp definition caused by objects being at different distances from the lens, and this must be obtained by the use of a diaphragm. Assuming that a photograph is to be made of two objects, one of which is ten and the other eleven feet away, the former will be in sharp focus at a greater distance behind the lens than the latter. This is due to the fact that the rays of light from a more distant object are more violently refracted as they pass through the lens, owing to the angle at which they meet the spherical surface. The difference in refraction is less acute at the center of the lens, and increases towards the outside areas. If, therefore, only the rays which pass through the central areas are used, they will focus more nearly in the same plane and create the impression of sharp definition. Diaphragms, usually of the type known as iris, are therefore used to exclude conflicting rays, and the aperture may be regulated from that which affords the use of the full opening of the lens to a tiny hole no bigger than the point of a lead pencil. Decrease of the lens aperture naturally decreases the amount of light which may enter, and correspondingly increases the time of exposure necessary to obtain the proper photographic image.

Another form of lens correction is for chromatic aberration, the effect of which is somewhat similar to the diffusion caused by spherical aberration but is caused by varied refraction of the colors in light. For this purpose lens glasses of special physical characteristics are used, and by their proper combination, together with the means employed to overcome spherical aberration, highly corrected photographic objectives are obtained.

Hardly less important than the lens is the camera equipment, the variety of which is almost endless. The essential features are that it shall provide a means for carrying the lens in one end and the photographic plate or film in the other, be light-tight and have an arrangement for focusing adjustment. Some cameras are constructed for so-called "universal focus lenses", and require no focusing device, but the name is misleading. It is a well-known optical principle that objects in different planes cannot all be focused with critical definition without focusing adjustment. The diaphragm is used to approximate this ideal, and lenses are made for fixed focus cameras which apparently define sharply objects which are in different planes.

As a matter of fact, however, they are "universally out of focus" and have no plane of critical sharpness which produces the optical illusion of sharpness through all planes.

Focusing may be done visually or by measurement. The relation between the distances of object to lens, and lens to plate, is based on formulas and a focusing scale on the camera may be used. It is only necessary to judge or measure the correct distance from the lens to the object and then set the adjustment of the plate to the corresponding distance indicated on the scale. Visual focusing is accomplished by placing a ground glass at the back of the camera in the same plane as that which will later be occupied by the photographic plate. The sharpness of the image is then regulated by adjusting the distance from ground glass to lens until the required amount of definition is obtained.

LENS GRINDING AND POLISHING

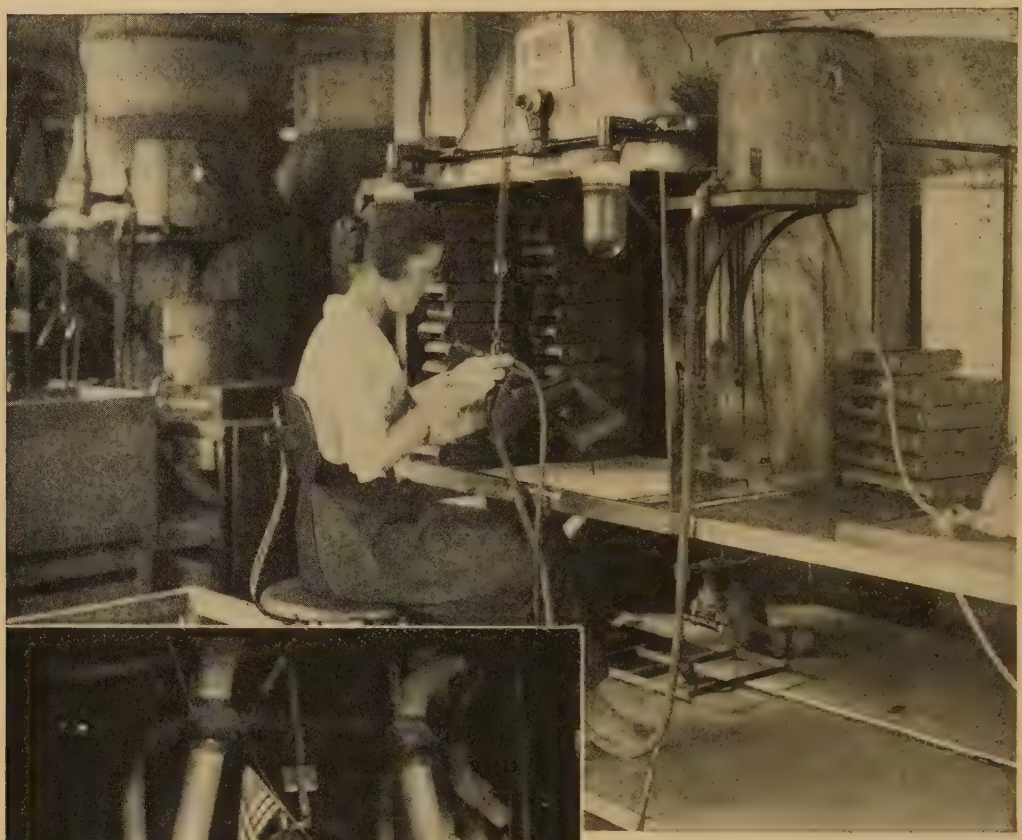
SETTING GLASS DISCS IN PITCH READY FOR FIRST GRINDING

LENSES SET READY FOR FINE GRINDING

Courtesy Eastman Kodak Co.

POLISHING; THE LAST OPERATION IN LENS MAKING

Lens glass is pressed into slabs at the pottery, and in that shape arrives at the lens factory. There, after exhaustive tests to prove flawlessness and to determine the index of refraction, each slab is cut into sticks by diamond-impregnated saws. These sticks are then sawn into cubes and placed in gas furnaces, where they are heated to the required softness for molding. They are then dropped into a die where a plunger, working under hydraulic pressure, presses the softened glass into a round disc. After the discs have been allowed to cool very slowly, they are tested for flaws and strains before being admitted to the grinding rooms. The process of grinding consists of gradually shaping the disc to the exact contour of the grinding shell. Coarse emery is used until the approximate curve is obtained, then fine emery with more accurate tools, until the surface is smooth and the curvature correct. The process of polishing a lens surface is similar, except that rouge is used instead of emery and the polishing shell lined with wax. It is a delicate operation, requiring hours, and an error in curvature of the smallest fraction of a millimeter necessitates the adjustment of the machine and further polishing until the error disappears. The centering and mounting of lenses are also important operations and require absolute precision. Lens making, in fact, involves mathematical computation of the first order and highly skilled workmanship throughout.



JAPANNING SMALL PARTS

The japan is sprayed on by means of air pressure and an atomizing nozzle and then baked in ovens.

SHAPING WOODEN PARTS OF THE CAMERA

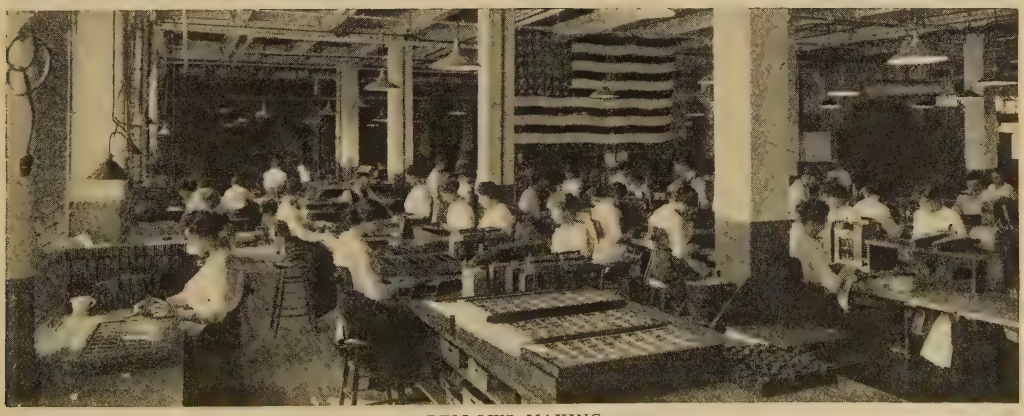
The operator is rapidly and accurately shaping the wooden parts of the camera with swiftly revolving cutters.

Notable among the time and labor-saving devices for focusing is the reflex type of camera. The box itself is not unlike the usual hand camera, but between the lens and the plate is a hinged mirror, which, placed at an angle, reflects the image from the lens to a sheet of ground glass in the top of the camera. Focusing is done in the usual way, and, by pressing a button or lever, the mirror may be instantly sprung upward out of the path of the image, simultaneously actuating a shutter release and causing the exposure to be made. Cameras of this type are much used in instantaneous photography, where it is essential that the image on the ground glass be visible up to the very moment of exposure.

Various devices, known as "shutters", are employed for regulating the length of exposure. The usual type is in the form of overlapping blades which can be readily separated and closed again by the controlling shutter spring, and is an integral part of the lens placed between two of the lens glasses. "Between the lens" shutters are usually constructed to operate

at speeds ranging from one second to about one two-hundredth part of a second, the variations being controlled by an adjustable air cushion. For extremely high speed work, the focal plane shutter is generally employed. This consists of an opaque curtain which travels directly in front of the plate and is provided with either a series of slotted openings of different sizes or the means of adjusting one slot. These run the entire width of the curtain and usually vary in size from one-eighth to one and a half inches. The shutter is wound on two rollers, one above the other, and is operated by a spring in the lower one. When released the curtain unwinds rapidly from the upper on to the lower roller, the slotted aperture crossing the entire area of the plate and creating the exposure. If the aperture is large and the spring tension low, an exposure equivalent to about one-tenth of a second can be made, but if the aperture is reduced to one-eighth of an inch and the spring tension increased, an exposure equivalent to one two-thousandth of a second is obtained. This does not represent the speed with which the slot crosses the entire surface of the plate, but rather that with which the one-eighth inch aperture crosses a corresponding area of the plate. Those who are familiar with pictures of racing automobiles will recall that their wheels appear elliptical. This effect, shown in the illustrations of the chapter Marvels of Speed, is characteristic of that produced by the focal plane shutter. The image of the car being reversed by the lens, the bottom of the wheels is the first part to be exposed by the traveling curtain of the shutter. By the time the slotted aperture reaches the image of the top of the wheels, the car has traveled forward a material distance and its image on the plate is further advanced than when the exposure began. This is what gives the elliptical effect to the wheels, and although it is a distortion, it tends to convey a graphic idea of speed and motion. Were the shutter arranged to run from the bottom of the plate upward, the car would appear to be leaning backward.

In regard to the various types of photographic emulsions, the wet plate, evolved



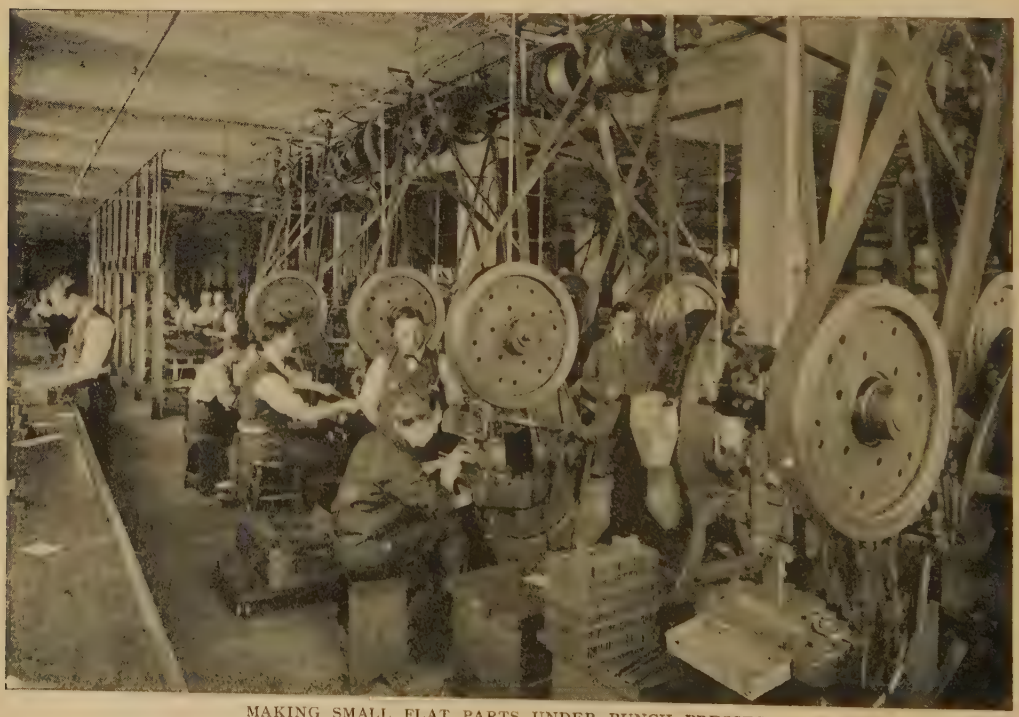
BELLOWS MAKING

The lining of the bellows, which is of rubber-covered cloth, is glued on a special form and attached to an aluminum frame, front and back, to brace it. Paper strips for stiffening the bellows and locating the folds are then automatically glued on by a special machine, the outside leather covering is added, the forms removed and the increases put in by hand.

SOME OF THE OPERATIONS INVOLVED

BATTERY OF AUTOMATIC SCREW MACHINES

Various round parts like screws, rivets, bushings, etc., are turned out here from rods fed through long pipes. The weekly output is 1½ million parts, which can be increased to 2 million.



MAKING SMALL FLAT PARTS UNDER PUNCH PRESSES

There are also milling and drilling machines on which final operations, in flat and round parts, are performed. Perfect accuracy is a *sine qua non*.

IN MAKING THE CONVENIENT KODAK

WHERE THE SHUTTERS ARE ASSEMBLED

This is the most intricate operation of all. The small dimensions and multiplicity of the parts of the shutter bring it on a par with watchmaking.

GENERAL ASSEMBLY ROOM

Here the Kodak frame passes from bench to bench, down one aisle and up another, picking up parts as it goes along, until it becomes the finished camera.

from the daguerreotype is highly sensitive to white, blue, violet and other actinic colors, but is extremely insensitive to green, yellow, red, brown and similar colors. It is employed extensively in the photo-engraving process, but only for the purpose of making negatives of black and white subjects. Emulsions which are sensitive to various colors are called "orthochromatic", "isochromatic", "trichromatic", and "panchromatic", according to their degrees of relative sensitiveness to colors.

The emulsion usually employed for roll film is, of course, quite sensitive to the actinic colors and relatively also to green, yellow and red. Panchromatic emulsions, or those which are sensitive to the action of all colors, are usually employed on process plates for commercial purposes. Color filters are usually employed to restrain certain colors while others are permitted to act on the emulsion. The familiar "ray filter" of the amateur equipment, which is supposed to photograph clouds, produces this effect by restraining the blue of the sky, making it appear darker than the clouds, which then show by contrast. The color plates used for printing magazine covers are made by utilizing this principle, filters being used to isolate the component colors of the original. This is called "color separation", and is based on the fact that color filters transmit their own and restrain or absorb all other colors.

One of the most interesting facts in photography is that the action of light is cumulative. A ray so faint as to cause no sensation of vision will, if sufficiently exposed on a photographic plate, create an image. This is taken advantage of in making photographs of interiors by means of prolonged exposure. A dimly illuminated room may be photographed as though it were brilliantly lighted if sufficient length of exposure is given. This also applies to photographing heavenly bodies which are so far distant as to have no effect on the eye whatsoever, even through the most highly powered telescope. Stars which have never been seen have been recorded and charted by means of photographs produced by protracted exposure.

Reproduction of color by means of photography has been accomplished by the use of color filters and the color-sensitive photograph emulsions. There have been numerous types of color photographic plates devised, notable among which is the Lumière autochrome. These are coated with a color screen consisting of grains of dyed potato starch. They are of three colors: orange, green and violet, and are spread in a uniform mixture over the entire surface of the glass plate and held in place with a waterproof varnish, the spaces between the grains being filled in with an opaque substance. The panchromatic emulsion is coated on top of this color screen, and when exposure is made the plate is placed in the camera with the glass side toward the lens, thus causing the image to first pass through the dyed starch grains before it reaches the emulsion.

The colors of the object pass through the dyed grains of corresponding colors and are restrained or absorbed by all others. Thus orange is transmitted by the orange starch grains but is absorbed by the violet and green ones, and so on. The autochrome plate is developed as a positive instead of a negative by subjecting it to the action of potassium permanganate instead of the familiar hypo. The result of this action is that one sees the colors of starch grains which reproduce the colors which have been transmitted. Thus orange grains are visible where orange appears in the original. This action is duplicated with the green and with the violet, and throughout all combined colors, and a photographic image in colors results. It is a transparency, and therefore must be viewed by transmitted light.

Practically all color photographic processes employ the method of "color separation" by using filters of orange, green and violet. On some plates they are in the form of minute squares, triangles or lines. Another method employs separate negatives for each color separation. Positives, each dyed a color complementary to the taking color, when superimposed produce the color image. Superimposition may be done on paper or other suitable material or on a transparent base like glass.

WEALTH AND WELL-BEING

The True Nature of Wealth, and the End and Aim of Human Effort in Trade and Industry

THE VALUE OF AMERICAN ACCUMULATIONS

THE aim of commerce is to increase wealth, and probably everyone thinks, in the words of John Stuart Mill, that he "has a notion, sufficiently correct for common purposes, of what is meant by 'wealth'". As is often the case when commonly used terms come to be analyzed, however, wealth is a thing exceedingly difficult to define. Want of clear thinking upon the subject long hampered and impeded the efforts of civilized countries to become wealthy. The use of money as a medium of exchange, and the obvious suitability of the precious metals for the purposes of money, led to the fallacious belief, entertained for centuries, and even in some quarters surviving to this day, that wealth solely consists of the precious metals, or of money. So firmly was this belief held that the trade policy of many countries came to be based upon it, to their grievous hurt.

It was thought that if a country had gold and silver mines it was a naturally wealthy country, and that its chief object should be to retain its gold and silver within its borders. On the other hand, if a country lacked gold and silver of its own, its main object was held to be to get as much as possible of the precious metals from other countries, and to keep it. That is why it was that the ancient idea of colonization was such a complete failure. The Spanish adventurers who discovered the New World looked upon it as a happy hunting-ground for gold and silver. They passed by the real wealth of the countries they ravaged in pursuit of Eldorados.

Commerce was infected by the same idea. It was thought that the sole end and aim of foreign trade was to export goods to other countries, and to obtain payment in gold and silver, thus adding to the wealth of the nation. Conversely, it was thought that it was ruinous to import because, as payment had to be made in money, wealth was accordingly lost. This theory of trade, known as the "Mercantile Theory", had for its golden rule that the more largely exports exceeded imports, the better for a country, since the balance represented gain in money. The idea of trade as a matter of mutual benefit had not been conceived; the notion was that commerce was a struggle between the nations of the world to win as much gold as possible.

It is quite easy to see how these absurd ideas came to have such a hold, not only on the popular mind, but even upon statesmen. We commonly talk of wealth in terms of money. We say that so-and-so is "worth" so many million dollars, or that a rich man has "plenty of money". What we really mean is that a millionaire possesses property which is worth so much, measured by the definite amount of gold which we call a dollar; we do not mean that he actually came to possess gold to the value of a million gold dollars. It is true that a single millionaire, who cared to sell out all his possessions, could change them into gold, and actually come to possess a million golden dollars, but if all our millionaires tried to do so, they would fail, for there is only about $3,000,000,000

or so of gold in the United States. The accumulated wealth of the United States probably amounts to $300,000,000,000 or more, as we shall see presently, but all that that means is that, measured in terms of the dollar, the actual capital has the exchange value of 300,000,000,000 dollars, not that 300,000,000,000 dollars actually exist.

What would happen if our national property were suddenly changed into dollars

Indeed, if the $300,000,000,000 worth of property were suddenly changed into dollars we should be poorer and not richer. We should perish, for gold is intrinsically one of the least useful of metals. All we want of gold is a very small amount for ornamental purposes, and a larger but by no means enormous quantity for currency purposes to facilitate the exchange of commodities. What we require in wealth are a thousand and one useful and pleasurable commodities to sustain our lives in health, comfort, and happiness. The truth about the precious metals is that while gold and silver are particular instances of wealth, they do not solely constitute wealth, but, themselves forms of wealth, are a convenient means of transferring and measuring other forms of wealth.

The word "wealth" has an interesting etymology. The Anglo-Saxon *wela* meant "well-being", and gave rise to the Middle English "welthe", and later to our "wealth". There can be no question that well-being — individual, social, and national well-being — should be the supreme aim of all human activity, and that "wealth" and "well-being" should always express the same idea. Economics, the science of wealth (etymologically, the science of house-law or husbandry), has to take account of the fact, and the modern economist avoids many ancient errors by constantly reminding himself of it. By the teaching of economists, wealth consists of all things that satisfy wants (*i.e.*, that possess utility), which can be transferred or exchanged, and which, because they are limited in supply, have value in exchange.

Proofs that utility alone is not a criterion of wealth

If we take the first parts of this definition alone, we have a statement which is true but incomplete. All wealth consists of more or less desirable things which satisfy some want or need, but, on the other hand, it is not everything which supplies a want which can be called wealth. Air, for example, is a prime necessity of human existence, but it is not wealth, because under ordinary circumstances it is procurable in unlimited quantities by everyone. While invaluable to the human economy it has no value in exchange. Thus also it is with water in a well-watered land with a sparse population. We see clearly that utility alone, however great, is not a criterion of wealth in the economic sense. Indeed, we may have the curious paradox that the pursuit of wealth in the economic sense may deprive us of invaluable non-exchangeable utilities, and therefore of well-being. For example, a clerk, finding it necessary to earn wages, may hire himself out to work under conditions in which, through lack of a non-transferable or non-exchangeable commodity — fresh air — he may lose his health. Here in the effort of obtaining economic wealth he loses something which cannot be classed as wealth, but yet is more indispensable than any other thing.

Thus also it is with another prime necessity of human existence — free access to sunshine. Sunlight is not wealth, and yet it is beyond price. It satisfies a great want, but it is in ordinary circumstances unlimited in supply and without value in exchange. In pursuit of those exchangeable goods of limited supply which are wealth by our definition, millions of men place themselves under conditions in which, for lack of sunshine, they lose health, strength and even life itself.

The solution of these paradoxes is curiously simple. When we say that water in a well-watered land is not wealth, we are thinking of water in the abstract, not a particular unit or increment in the supply of water, which may, under particular conditions, have a very high exchange

value, just as air and light, under special conditions, may have a high exchange value. As a matter of fact, the world does not value things in the abstract, but it puts a value upon concrete units of things. This simple and elementary, but elusive, fact must be grasped and retained by anyone who wishes to master the principles of economics. From the fact that utility attaches not to things in the abstract, but to particular units of things, and from the further fact that the utility of *additional units* of the supply of any good, such as air, or light, or water, or bread, diminishes as the supply increases, there follow some of the most important doctrines of supply and demand.

Things not valued in the abstract but in their concrete units

Under most conditions, air has no value, and therefore does not constitute wealth. This is because the satisfaction of our wants does not depend upon the possession of *any particular* cubic foot or cubic yard of air. Any particular "increment" of air can be spared and, under most conditions, there will be more than enough left to go around. So with water in a well-watered land. But take the case of the traveler in the desert with half a cupful of water left in his canteen: the utility of that particular quantum of water is extremely high, for life itself may depend upon it.

But if you put the same man beside a fresh, bubbling fountain, where he is able to refill his cup when he throws one cupful away, then we are forced to the conclusion that under these changed conditions the utility of *a cup of* water, and hence its value, is practically zero.

The pursuit of economic wealth often means the loss of a nation's vitality

The important point involved is that the satisfaction of the traveler's wants does not depend upon any particular *unit or increment of the supply*. Therefore, no particular increment or unit of the supply has value. This should make clear what we mean when we say that wealth consists, not of things in the abstract, but of specific and definite units of things.

Thus a nation possessing economic wealth may easily lose a great part of its vitality if it sets the pursuit of economic wealth above the pursuit of well-being. It was the ignoring of this all-important fact by certain economists of their day which earned the scorn of Carlyle and Ruskin. In "Unto This Last", Ruskin wrote, in 1862: "There is no wealth but life. Life, including all its powers of love, of joy, and of admiration. That country is the richest which nourishes the greatest number of noble and happy human beings; that man is richest who, having perfected the functions of his own life to the utmost, has also the widest helpful influence, both personal and by means of his possessions, over the lives of others."

Life, "with all its powers of love, of joy, and of admiration", is not wealth within our definition; and it is because economic wealth is capable of destroying life as well as of sustaining it that individuals and nations cannot entirely guide themselves by the principles of the old economists.

The true test of wealth—utility and the promotion of social well-being

If we desired to make a definition of "wealth" coincide with a proper conception of well-being, we should make it read: "Wealth consists of all things that satisfy wants (*i.e.*, that possess utility), which can be transferred or exchanged, which because they are limited in supply have value in exchange, *and which promote individual and social well-being.*"

From the beginning the life of mankind has been a pursuit of wealth or what is esteemed for wealth. The primitive man was compelled to a ceaseless struggle for a bare existence. Land was his in plenty, but nature, as yet uncontrolled and untamed, yielded little to his strivings, and in the struggle for what little she afforded the savage had to fight hard with his fellows. The ascent to tools, to cultivation, to domestication of animals, to ordered communities, was a slow and painful one; and it was long before any considerable number of men won, either through the voluntary service of their fellows or through the institution of slavery, freedom

from hard and bitter toil. As the production of wealth was made easier, and the standard of life rose higher, the pursuit of wealth became no less ardent.

The expansion of the desire for wealth with the growth of man's needs

Each increase in the standard of living creates new wants in us. Our wants and supposed needs are regulated by custom, and we are not content with less than we know of as desirable things. Man's wants are thus indefinite, and it is impossible to put bounds to his desire for wealth. This is as true of the moral as of the selfish. The latter desires infinite command of wealth for himself; the former desires the indefinite command of the means of life by the multitude.

The ascent of man does not, therefore, free him from the necessity of labor or the pursuit of wealth. It may, however, eventually free him from unremitting labor; it may confer upon all men the enjoyment of a high standard of life, in which there shall be considerable elements of freedom and leisure.

We all know that labor varies greatly in character, that some tasks are agreeable and others irksome and monotonous. It is not the distinction between mental and manual labor which we refer to. Either mental or manual tasks may be laborious; either, again, may be stimulating and agreeable. It is a physical effort to climb a mountain, but the thing is often done for sheer joy of conquering a physical difficulty and triumphing over natural obstacles.

The pursuit of wealth in relation to irksome labors

Many manual tasks calling for considerable physical effort, such as gardening or carpentering, are often taken up as hobbies by persons of leisure. The truth is that labor is irksome when it is pursued without variety for long hours, when little of skill is exercised in its performance, when it is exceedingly laborious, or when it brings little reward.

Modern society has made us accustomed to the use of, or desire for, a multitude of complex articles. Our houses, our clothing, our every appurtenance of pleasure or sport, call for a huge variety of articles which, if made pleasurably by individuals, would take so long to make that few of them would be available. We solve the problem of producing a large output of labor by machine production. As a result, manufacturing work becomes irksome in the extreme. To make a shoe entirely by hand was a task which yielded variety and pleasure in labor. The task may have been a pleasant one not only because it was varied, but also because it yielded a *complete product* which the workman could see and handle and call his own. Variety of tasks and the joy of creative work are found hand in hand when the individual worker can feel that he himself is responsible for a complete product.

Has the advent of machinery had a degrading effect on labor generally?

Not so with the modern shoe factory. Shoes are now produced by complicated machines, and each individual part of a shoe is made by a separate machine. Consequently, the worker told off to tend the separate machine does nothing all day long but what may be a wearisome, mind-destroying task. Hour after hour, day after day, week after week, year after year, he is found fastening heels, or holding up shoes to the lasting-machine. The machine itself is a great triumph of the human intellect; in the working of the machine, some say, is involved the degradation of labor.

But, on the other hand, certain thoughtful observers and students of the problem have questioned whether the advent of machinery has really had in general a degrading effect upon the industrial employments. Thus, for example, Professor T. N. Carver, dealing with this very case of the making of shoes, has suggested that other considerations should be taken into account:

"Looked at broadly, is the average work of a laborer in a machine industry less dignified, less agreeable, less humanizing than it was before the industry reached the machine stage? From the nature of the question, it is dangerous to dogmatize,

because neither the affirmative nor the negative is capable of being demonstrated. The negative view seems to rest mainly upon the assumption that it is more dignified to be occupied with a great many purely mechanical operations than with a very few. The old-fashioned shoemaker, for example, was largely occupied with purely mechanical operations, most of them of a very elementary nature, such as a machine can do quite as well as a man. Each of these operations required great concentration of attention, leaving him very little opportunity for other forms of mental activity. He was the slave of each particular task as truly as a modern machine worker can be said to be the slave of his single task. But the old-fashioned shoemaker had to turn from one kind of work to another. This increased the difficulty, and, on the whole, required of him a greater amount of concentration than is now required of the operator of a machine. The latter, who has but one routine task to learn, learns it easily, and can carry it out without very intense concentration of mind. His mind, therefore, would seem to be freer than that of the old hand worker, though there was more variety to the work of the latter. Whether this greater variety is to his advantage or disadvantage would be difficult to determine off-hand. It looks as though the operator of a machine in a shoe factory, being relieved of the necessity of acquiring several forms of specialized manual dexterity, would be in a better position for free mental activity than the old-fashioned shoemaker."

One thing is clear, however, and that is that we should not be content to go back to that simple primitive life which calls for a minimum of effort because wants are few and little of material goods is needed to supply them. How, then, is labor to escape from the irksome consequences of supplying by machinery the complicated and extensive needs of modern mankind? The answer to this question may happily be found in the perfecting of the organization of mankind for the labor which has to be done, and the consequent winning of leisure.

In any event we do not want to go back to the simple, primitive life

This hope becomes eminently reasonable when we consider the extraordinary capacity for rapid production which has already been won. We have referred to shoe manufacture. A visit to a modern shoe factory shows that the entire work of making a shoe — the addition of the few moments with which each of the many machines is concerned with a particular pair of shoes — is very little. Similarly, if we go to an automobile factory, we find that the aggregate of the labor now needed to produce an automobile is ridiculously small. Consideration shows that machine power is so great that, although its individual processes are necessarily monotonous, the proper organization of the working members of the community would suffice to get done all work of the kind that needs doing in a very short space of time. We see our way to the possibility, through machine production, of working days so short as to give to the operator of the machine a large leisure in which to develop his many-sided powers. We see our way to the more nearly universal distribution of leisure.

It is possible, however, that in present-day discussions of economic problems we attach too much importance to an increase in leisure. The working hours of the day absorb, and will continue to absorb, a large part of humanity's energies. The peoples and the nations which have succeeded in the struggle for existence are not those which have put a high value on leisure, but those which have combined the qualities of industry and thrift. Rightly seen, the economic problem is not so much that of lessening the amount of work to be done as that of making it more agreeable and attractive to the worker, and of directing it into channels which will be of maximum usefulness to society. From time immemorial the world's wise men have observed that there is no happier man than he who delights in the work he has to do, and who is therefore able to put his energies and his enthusiasm into it with all his heart.

Not less but better and happier work the right ambition

The radical social reformers who count upon the ultimate reduction of the working day not only to four or five but even to two or three hours are not only overoptimistic but also are failing to see the real goal of human progress. Not less work, but better work and happier work are more serviceable ambitions for any people. It may be too much to hope that what we may call the artistic instinct, the irresistible impulse toward the expression of one's personality in one's work, may come to be the common possession of the world's workers. But progress toward such a happy condition is probable.

One of the greatest present disadvantages of the machine system may ultimately become one of its greatest advantages. By subdividing, simplifying and standardizing manufacturing processes, it reduces them to routine. It introduces monotony of occupation. It calls for a large number of routine tasks. But it happens that it is just these monotonous and routine tasks which invite the further use of machine processes. When a task becomes simple and standardized it is fairly certain to be taken over sooner or later by machinery. Mechanical stokers, mechanical press feeders, mechanical filling and bottling devices and other machines have already taken over certain monotonous employments. Further applications of machinery to simple and standardized processes are inevitable. It may well be that the cure of some of the evils of the machine system may come through its own further perfection.

Adam Smith and John Stuart Mill on productive and unproductive work

The desirable commodities which constitute wealth may be material goods or immaterial goods (services), and we may find immaterial goods in a concrete form. The services of a carpenter, bricklayer, machinist, or longshoreman satisfy wants, and are properly termed wealth. We may see any or all of these embodied in material form. Ten thousand bricks in a brickyard are worth less than ten thousand bricks built up as a wall, because not only has other material been incorporated in the wall, but the bricklayer's labor has taken a concrete shape. So it is also with the services rendered by postmen, policemen, doctors, or lawyers, whether or not they take concrete form.

Such has not always been the opinion of political economists. Both Adam Smith and John Stuart Mill — the two greatest names in the history of English economic thought — held that those services only are truly productive which are embodied in "durable and vendible commodities". Adam Smith said:

"The labor of some of the most respectable orders in society is, like that of menial servants, unproductive of any value, and does not fix or realize itself in any permanent subject, or vendible commodity, which endures after that labor is past, and for which an equal quantity of labor could afterwards be procured. The sovereign, for example, with all the officers both of justice and war who serve under him, the whole army and navy, are unproductive laborers. They are the servants of the public, and are maintained by a part of the annual produce of the industry of other people. Their service, how notable, how useful, or how necessary soever, produces nothing for which an equal quantity of service can afterwards be procured. The protection, security, and defense of the commonwealth, the effect of their labor this year, will not purchase its protection, security, and defense for the year to come. In the same class must be ranked some both of the gravest and most important, and some of the most frivolous professions: players, buffoons, musicians, opera-singers, opera-dancers, etc. The labor of the meanest of these has a certain value, regulated by the very same principles which regulate that of every sort of labor; and that of the noblest and most useful produces nothing which could afterwards purchase an equal quantity of labor. Like the declamation of the actor, the harangue of the orator, or the tune of the musician, the work of all of them perishes in the very instant of its production."

Inconsistencies and absurdities inherent in Smith's and Mill's contention

Various writers since Smith and Mill have called attention to the inconsistency and absurdities that are inherent in such contentions. For example, by Smith's criterion, a violin maker is productive, and a violinist unproductive, although the only purpose of making the violin is that it may be played upon! In a similar way, the engineer who designs a bridge is productive, but the professor in a technical school who taught him how to design bridges is unproductive! Caruso was unproductive when he sang in the Metropolitan Opera House, but he was productive when he sang for a phonograph record! It is clearly impossible to qualify services as productive and unproductive simply because some are directly rendered to the consumer, while others take the intermediate form of marketable commodities. After all, everything that satisfies a human want must be held to possess utility, and from one point of view it is unimportant whether the want be satisfied by a service directly rendered, as by a musician, a teacher or a physician, or result in the increase of more or less durable commodities, as do the services of artist, author, and the manufacturer of medical supplies.

Their use of the words "productive" and "unproductive" misleading

Nevertheless, there is a fundamental truth in the doctrine advanced by Smith and Mill, although their use of the words "productive" and "unproductive" is misleading. The distinction they sought to make is really one between work which provides for present wants, and work which adds to a country's stock of capital. From the point of view of the consumer, the difference appears as the distinction between spending and saving. The accumulation and increase of national wealth depends not only upon production; it also necessitates thrift. No nation, any more than an individual, can "eat its cake and have it, too". There would, of course, be no purpose in producing solely with an eye to the increase of future wealth; thrift should not become parsimony. But, as human nature is constituted, there is little likelihood that the people of a nation, taken as a group, will need to be exhorted to save less and spend more. No one has ever assigned too large a measure of thrift as the cause of the decline of any people. For practical purposes, the lesson which needs to be taken to heart is that which Smith and Mill taught.

The natural collective wealth of a nation difficult to express in dollars and cents

Apart from wealth the result of labor, a nation owns collectively wealth which it is difficult to express in values. The United States, for example, possesses a fine geographical position in the world which facilitates trade. It has a magnificent seaboard and fine natural harbors. It is favored with an excellent rainfall, temperate climate and great rivers. All these things are public or collective goods which count enormously in its economy, but which, obviously, cannot be valued in dollars.

As contrasted with these free goods which undoubtedly constitute an important part of our social or collective wealth, we must be careful to identify those goods which are *publicly owned*. These are goods which are not free, but which are the objects of property rights, such property rights being vested, however, in the public rather than in individuals. The increase of public wealth is a remarkable feature in modern economic development.

Just what constitutes public wealth as contrasted with private

The field of what constitutes public, as contrasted with private, wealth varies as among different countries. Public buildings, court houses, institutions, libraries, universities, lands, street railways and other public utilities, steam railways, forests and even mines are public property in one country or another.

Just as public property is a part of our national wealth, so the services rendered by the government must be counted along with the services rendered by individ-

uals as part of the nation's annual wealth product. In addition, to the common benefits of nationhood, there are the public services which are provided by the State as a whole, or by local authorities within it, which are free to all, and which are paid for by the citizens as taxpayers or as ratepayers. These include defense (Army and Navy), education, policing, roads, bridges, parks, museums, drainage systems, public health services, public lighting and so forth. A moment's thought will show that it is a sort of framework of individual life which is formed by these public services, or, to vary the metaphor, that individual life and work are, as it were, embroidered upon a general fabric sustained by the community acting as a whole.

A modern nation not unlike a club, its dues paid in work

We are very prone to regard established things as commonplace, but the gigantic communal arrangements of modern societies, that make civilized life possible and give a certain security to all, are by no means commonplace. To sustain them raises difficult problems of taxation and management, which are of increasing importance as society grows, and as it is felt that a wider communal life is needed. A modern nation becomes more and more a club which furnishes amenities in return for a subscription, nominally of money, but actually of work. How far the process will be carried, and to what extent wealth will come to consist of "public goods", we do not know, but the tendency in this as well as in other countries is to widen the range of public provision.

The growth of the national wealth of the United States in seventy-five years

What wealth have the people of the United States so far accumulated? The inquiry is one of deep interest, even of fascination. We have been cultivating, manufacturing, and trading, in large and in small, for many years. What sort of a stock of wealth has been accumulated in all this time?

The United States has more satisfactory and complete statistics of national wealth than any other country in the world, but, at the best, such figures are unsatisfactory and likely to be misleading. We shall return to that point presently. In the meanwhile let us note the vast apparent increase in the nation's wealth from $7,500,000,000 in 1850 to an estimated total of $325,000,000,000 in 1922, — a forty-fold multiplication in a period that is no longer than the normal span of human life.

GROWTH OF THE NATIONAL WEALTH OF THE UNITED STATES, 1850–1922

1850	$ 7,500,000,000
1860	17,000,000,000
1870	31,200,000,000
1880	43,600,000,000
1890	65,100,000,000
1900	88,500,000,000
1904	107,100,000,000
1912	187,700,000,000
1922 (estimated)	325,000,000,000

No other nation has ever achieved such a total; it is probable even that on a per capita basis, the general level of wealth in the United States is the highest the world has ever known. The figures used are accurate enough, we are confident, to justify these general inferences from them. But, as we have said, they have certain necessary limitations.

Difficulty of obtaining exact figures and expressing in terms of money

In the first place, it is difficult and often impossible for the Bureau of the Census to get accurate information on all these various points. In the second place, the only way in which national wealth can be expressed as a total is in terms of a common measure — money. Unfortunately, money itself is not stable in value, and its fluctuations will be reflected in changes of the total wealth of the country. For example, the increase between 1860 and 1880 is partly, although not wholly, explained by the rise of prices during the greenback period following the Civil War. Again, the apparently slow increase in national wealth between 1880 and 1900 — a period in which it barely doubled — may be due in part to the gen-

eral downward tendency of prices during most of that period. The increase in wealth revealed in 1922 is partly to be explained by the increase in prices which had begun as early as 1897. Finally, the enormous figure of $320,000,000,000, which we have set down as a conservative estimate of the national wealth in 1922, is in part a reflection of the general rise in prices during the Great War and the years immediately following.

NATIONAL WEALTH OF THE UNITED STATES IN 1900 AND 1922

Form of Wealth	1900	1922
Total	$88,517,306,775	$320,803,862,000
Real property and improvements taxed	46,324,839,234	155,908,625,000
Real property and improvements exempt	6,212,788,930	20,505,819,000
Livestock	3,306,473,278	5,807,104,000
Farm implements and machinery	749,775,970	2,604,638,000
Manufacturing machinery, tools and implements	2,541,046,639	15,783,260,000
Gold and silver coin and bullion	1,677,379,825	4,278,155,000
Railroads and their equipment	9,035,732,000	19,950,800,000
Street railways, etc.		
Street railways	1,576,197,160	4,877,636,000
Telegraph	211,650,000	203,896,000
Telephone	400,324,000	1,745,774,000
Pullman and cars not owned by railroads	98,836,600	545,415,000
Shipping and canals	537,849,478	2,951,484,000
Pipe lines		500,000,000
Privately owned water-works	267,752,468	360,885,000
Privately owned central electric light and power stations	402,618,653	4,229,357,000
All other		
Agricultural products	1,455,069,323	5,465,796,000
Manufactured products	6,087,151,108	28,422,848,000
Imported merchandise	424,970,592	1,548,666,000
Mining products	326,851,517	730,296,000
Clothing and personal adornments, furniture, carriages, etc.	6,880,000,000	39,816,001,000

Again, it should be noted that what we have called free goods, although properly items of social wealth, cannot be included in these figures. Moreover, much publicly owned property is not and cannot be included. What is the value of our rivers, harbors and lakes? These are excluded from the statistics, although canals are included. Most important of all, however, is the fact that such statistics are in part made up of items which are of a purely *competitive*, rather than social, value. For example, the value of railroads and their equipment is obtained by capitalizing railway earnings. But this method is not and cannot be used systematically throughout the table. The "good will" of business establishments is not included, although the so-called "franchise value" of railway properties is.

We must always keep in mind the paradoxical fact that an increase in wealth may come from increasing scarcity as well as from increasing abundance. Such, for example, is the case of the enormous increase in the figures for land values between 1900 and 1912. It will be noted that the census estimate of national wealth for 1912 exceeds the similar estimate for 1900 by about a billion dollars. Possibly a third of this increase represents the actual and real increase in the quantity or amount of economic goods within the United States. The balance of the increase consisted very largely of the appreciation of the *value* of land and of other durable forms of wealth. And it must be remembered that, since the statement does not include all the valuable property rights of individuals, it understates, rather than overstates, the aggregate value of the exchangeable wealth of the country.

For Canada, the best estimate seems to be one published in the *Journal of the Canadian Bankers' Association* for 1915:

	Millions of Dollars
Farm values	3,300
Mines and forests	800
Railways	1,100
Urban real property	3,000
Manufacturing machinery	300
Live stock and implements	900
Stocks of raw materials	800
Carriages and motors	600
Specie	200
Investments abroad	100
Total	11,100

In subsequent years, of course, there has been a vast increase in the money value of the wealth of Canada, which, at the present time, cannot be far short of twenty-five billions of dollars, and it rests upon diversified natural resources and a population of proven efficiency.

We present in the table below as complete a summary as is possible of the estimates of wealth of some of the most important countries. The credit for bringing together these estimates, and for making or revising some of them, belongs to Sir Josiah Stamp, the leading English authority on statistics of wealth and income. It is apparent that the nations covered in this table fall into three groups: first, those whose per capita wealth is relatively large (over $1000); second, those whose per capita wealth is notably small (less than $500); and third, those countries which occupy intermediate positions.

THE WEALTH OF GREAT NATIONS 1914

Country	Estimate Based on Work of	Approximation to Accuracy: Grade*	Amount in Millions of Dollars	Dollars per Capita
United Kingdom	Stamp	I	71,000	1,550
United States	Census, King	II	204,000	2,060
Germany	Helfferich,	II	80,500	1,200
France	Pupin, Thery	II	60,000	1,500
Italy	Gini	III	21,800	625
Austria-Hungary	Fellner	III	30,200	590
Spain	Barthe	IV	14,300	700
Belgium	Official	III	6,000	765
Holland	Stuart	III	5,100	815
Russia	Neymarck	IV	60,000	410
Sweden	Flodstrom, Fochlbeck	III	4,570	820
Norway	Gini	IV	1,100	440
Denmark	Gini	IV	2,400	860
Switzerland	Gini	IV	3,900	980
Australia	Knibbs	I	7,500	1,550
Canada	Bankers' Association	II	11,100	1,460
Japan	Stamp	IV	11,700	210
Argentina	Bunge	III	11,170	1,650

*Grade I. Estimate is not likely to be inaccurate to a greater extent than 10 per cent.

Grade II. Estimate is not likely to be inaccurate to a greater extent than 20 per cent.

Grade III. Estimate is not likely to be inaccurate to a greater extent than 30 per cent.

Grade IV. Estimate *may* be inaccurate to a greater extent than 40 per cent.

In the first group are certain countries which by common consent would be conceded to be the most advanced in their general economic civilization, and which not only have large natural resources but which also have led the way in the application of science to the work of wealth production. These countries, which stand out clearly in the table, are the United States, Argentina, Great Britain, France, Australia, Canada and Germany. At the other extreme are Japan, Russia and Norway, with Switzerland, Denmark, Sweden, Holland, Belgium, Italy, Spain and Austria-Hungary occupying the intermediate position.

The high position occupied by the English-speaking peoples is notable. This is not only because, with characteristic enterprise, they have sought out and settled those portions of the earth where nature has been most generous. It is also because, in their political and economic organization, they have left a reasonably free scope for individual enterprise and initiative, and because they have been quick to develop and make use of the methods which science furnishes. Germany, whose natural resources, aside from coal, are in no way notable, nevertheless makes an extraordinarily good showing. Her relatively high position is to be attributed in large measure to the scientific organization of her industry and of her economic life. France, with respect to per capita wealth, occupies even a higher position than Germany, — a position comparable to that of Australia and Canada. In France thrift, industry and fertile soil have done much to offset a paucity of coal and a resulting handicap in the development of large-scale industries.

The net result of our study is to put new emphasis on the dominating importance of the human element in the wealth of nations. Bountiful supplies of the sources of mechanical power, fertile soils, favorable climate, harbors and waterways — these and other gifts of nature remain merely dormant and potential elements of a nation's wealth until they are quickened into life by the touch of human energies, guided by the knowledge science alone can give.

THE SEWING MACHINE

Why the Sewing Machine is Numbered with the Epoch-Making Inventions of the Age

ITS EARLY HISTORY AND RECENT DEVELOPMENT

IT has been justly said that one of the principal causes of the general prosperity of the American people is to be found in their wonderful adaptation of mechanical contrivances to take the place of manual labor. Of all the inventions devised to lighten the work of women in household and factory, certainly the sewing machine is the most conspicuous example. It has for its object only the seemingly insignificant function of fastening one piece of fabric to another, but its influence in ministering to the wants of the race has been so marked as to cause it to be numbered with the greatest inventions of this or any age.

In ancient times there was a simplicity of dress because the process of weaving cloth was slow and difficult, and there was great economy in the use of material for people's attire. The rich were distinguished from the poor more by the magnificence of the cloth they wore than by any special elaboration in the fashion with which their garments were made. There was little sewing then, and the making of clothes had not yet called into existence any special class of sewing-women. But in the 13th and 14th centuries commerce brought great wealth to Italy, and with it a new luxury of attire. The dress of both sexes became more elaborate. The Italians were the most handsomely dressed people in the world, and the city of Milan came in time to dictate the fashions, not only to Italy but to the north and east of Europe. It is even said to have given its name to the new art of millinery. With luxury of attire came a great increase in the amount of sewing; and when, two or three centuries later, the steam engine was set to work to drive the loom, and the manufacture of cloth began to be carried on, on an enormously increased scale and at a diminished cost, and people began to wear twice and three times as many yards of cloth as before, sewing gave employment to a special class of thousands of women and girls in all large cities. This occupation, which from earliest times seems to have been set apart as peculiarly belonging to women, eventually became overcrowded, the pay correspondingly low, and great poverty and suffering resulted.

In 1843 Thomas Hood published his famous "Song of the Shirt" to commemorate the privations of this class of women who lived by the needle, and it is a curious and interesting fact that about the same time the machine that was to relieve these women from the drudgery that had so long enslaved them was being perfected in America.

Notwithstanding these conditions, however, and the interest the machine aroused on its first appearance, the idea of sewing by the aid of a machine was not received by the women of those days with much enthusiasm. There was conspicuous skepticism that a machine could ever execute needlework as neatly, tightly, and as perfectly as deft feminine fingers. The centuries of acquaintance with the ordinary needle had created a prejudice and an opposition to anything but handwork which refused to be overcome in a single day. About the only change that had occurred in the manner of sewing since the dark ages was that at the beginning of the 19th century a steel needle was used instead of one of bone or wood.

It was industry, as represented by the factories, which demonstrated the possibilities of the sewing machine and eventually forced it into the household. Manufacturers of wearing apparel and other goods, for the production of which dependence had hitherto been reposed in the skill and dexterity of human fingers, recognized the many advantages accruing from machine-sewing. By its means not only was the cost of manufacturing reduced, but the output of a factory could be increased to a degree never previously considered possible, and that with a great reduction in the number of work people. So from the utilization of this invention sprang the countless immense modern workshops which specialize in the production of ready-made clothing for both sexes, and which enable all to dress better today, and at a fraction of the cost, than could our less fortunate forefathers.

How the introduction of the sewing machine changed the art itself

The introduction of the sewing machine necessitated a considerable modification in the art of sewing itself. Many of the early attempts to sew by machinery were along the line of imitating ordinary hand-sewing by the aid of a needle inserted into and drawn through the fabric by mechanical fingers or nippers, but all such inventions proved failures. It was found necessary to abandon altogether the conventional method of stitching and to devise other means of uniting fabrics better adapted to the capacity of machinery. In the crude machines developed by the earliest inventors, detached lengths of thread were used and there was no means or preventing a constantly varying length of slack. But soon mechanisms were devised whereby the thread could be worked up continuously from a reel or bobbin. An unvarying length of slack was thus presented at each stitch, and a uniform tightening up of each stitch was accomplished. In machine-sewing the thread is continuous from the fabric to the spool or bobbin, merely passing through the eye of the needle instead of being fixed in the eye as in hand-sewing.

It is evident, therefore, that the thread can only be passed through the fabric in a double or looped form. The most convenient means of accomplishing this is by having a needle with an eye near its point. The needle is pushed just far enough through the fabric to carry a loop of the thread to the other side, and then withdrawn. But instead of carrying back the loop of thread it has just introduced, this loop is retained or secured on the other side of the fabric by being interlooped with itself or with a second thread fed from a bobbin, and called a "filling thread". Another distinguishing feature in machine-sewing is the manner in which the length of the stitch is regulated. In hand-sewing, of course, the work is held stationary while the length of stitch is judged by the eye and the drawing up or tightening of the stitch is more or less variable. But in machine-sewing the work is moved under the needle step by step in such a way that both the length of the stitch and the drawing up, or tightening, is uniform.

While the invention of the sewing machine is commonly attributed to Elias Howe, whose machine, patented in 1846, contained most of the essential features of the present-day machine, it had been in process of evolution for more than a century previous to that time. The idea was originally that of an Englishman, Charles F. Weisenthal, who obtained a patent in 1755 for a crude device to facilitate the process of embroidering and a great many experiments were made in England toward perfecting the contrivance before American inventors directed their attention to the subject. As is the case with most mechanical inventions, the sewing machine is the result of the efforts of many inventors, although it is apparent that the most meritorious of these worked in ignorance of the labors and successes of others in the same field.

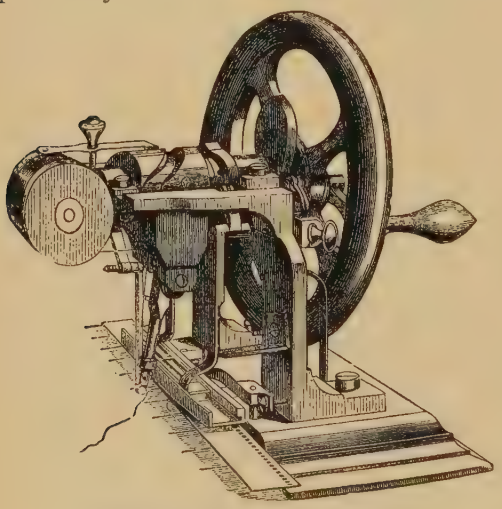
Weisenthal's invention, which proposed to use a needle pointed at both ends with an eye in the middle, and which was drawn backward and forward through the material by nippers operating on both sides, was never utilized to any very considerable extent.

Thomas Saint patented a machine for heavy sewing in 1790. It was mostly of wood, with an overhanging arm into which was inserted a vertical reciprocating needle, and an awl to go before it and punch the holes. On the top of the arm was a spool for giving out the thread continuously. The stitch was the same as Weisenthal's and was called the "tambour" or "chain-stitch". A loop was formed by thrusting the needle through the cloth or leather. A second thrust carried the bight of threads through this loop, making a second loop through which, in turn, the needle was thrust to form a third, the first loop being drawn up tight during the third thrust. This variety of stitch was used for many years in lightening the labor of heavy sewing. Saint does not appear to have considered the plan of superseding the hand needle for general work. Other minor inventions along this line soon followed but none of the machines was given much attention.

Like all labor-saving inventions, the sewing machine met with opposition. Working-men stood in dread of its introduction in the leather trades and fought against it with all the resources at their command. A French tailor, Barthelemy Thimmonnier, developed a sewing machine, also of the chain-stitch type, which was used to some extent in the manufacture of army clothing. Thimmonnier's machine is notable for carrying only a single needle, pointed to drive its own passage through the fabric, and notched at one side to carry the thread. The loop, or stitch, was formed by the thread being wrapped around the needle, which drew it back through the material. The latter then moved forward a certain distance to permit the needle to again descend. In this instance the loops forming the chain-stitches were made upon the upper instead of the under surface of the material. So favorably impressed were the inventor's friends with this machine that they advanced the ingenious tailor sufficient funds to equip a factory. The enterprise met with success and several years later eighty machines were at work. But the seamstresses and tailors did not view the new development with favor. Like the weavers who had construed Hargreave's spinning machine as a threat against their livelihood and had promptly destroyed the new-fangled idea, so even in enlightened France did a discontented mob of needle-workers raid Thimmonnier's factory and destroy his machines. Undismayed by this manifestation of mob violence and antagonism, he continued his efforts and built improved machines, but failing to receive further financial encouragement from his friends, who doubtless feared another outburst among the needle-workers if they attempted to reëstablish mechanical sewing upon a commerical scale, the disappointed inventor eventually abandoned his efforts.

Ingenious American inventors had now begun to make attempts to solve the problem of machine-sewing. The ideas of an eye-pointed needle and a double thread or lock-stitch are strictly of American origin, and that combination was first conceived by Walter Hunt of New York about 1835. The defects of the chain-stitch, which had constituted the salient characteristics of all previous machines, were fully recognized. As is well known, such a stitch may be easily and rapidly unraveled. The severance of loops here and there enables the intervening section of thread to be pulled out with ease. A stitch free from this disability was desired. Such an end could only be achieved by making each stitch a knotted unit. In other words it became necessary to lock the stitch, and the perfection of the loop in this manner came to be known as the "lock-stitch". In Hunt's machine a curved eye-pointed needle, carried in a vibrating arm, was threaded from the reel, penetrated the fabric, and thus formed a loop on the under side. At this moment a shuttle carrying a coil of thread came into play, and passed through a loop which, when the needle reascended, was drawn tight. In this manner the ordinary chain-stitch became locked. But owing to the prejudice against machine-sewing which still existed, this invention was not perfected and exploited. Hunt neglected to have his ideas patented and thereby lost an opportunity to make a great fortune.

The most epoch-making of all sewing machine inventions was now about to take place. Independent of Hunt and his predecessors, Elias Howe, a native of Massachusetts, directed his attention to machine-sewing in the year 1843. In 1844 he completed a rough model, and although made of wood and wire and crude in the extreme it contained most of the essential features of the modern machine. He patented this machine in 1846. Howe was the first to patent a lock-stitch machine, but his invention had the two essential features, the curved eye-pointed needle and the under thread shuttle which were invented by Walter Hunt twelve years previously.



ORIGINAL HOWE SEWING MACHINE

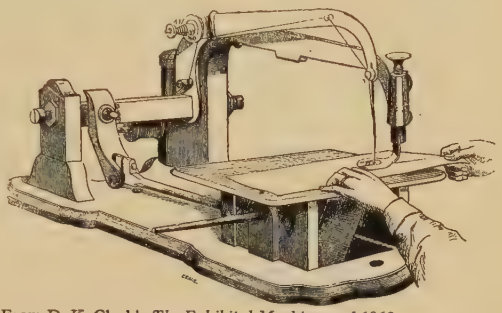
Although covering much of the same ground that Hunt and others had taken possession of before him, his machine was so novel in its combinations and forms as to be treated as a new invention. In addition to the other features he had a peculiar baster-plate to feed the cloth, and a device to give tension to the upper thread. It embodied the essential features of our modern machine, but was not itself a great success. Howe made a few specimen machines but they would not sell at first, and when they did, the purchasers could not make them work. The tension was not uniform, so that the thread formed large loops in one part of the seam and was too tight in another. The feeding motion was defective for want of continuity; the baster-plate had to be pushed back when it reached its forward limit, the cloth again fastened to it, and the plate again fed forward. Howe was a mechanic of small means, and could not himself raise the capital necessary for manufacturing. Unsuccessful in interesting capitalists in this country he sold his patent rights to an English firm but so little was the invention appreciated that for a time it was offered without success to many leading manufacturers and engineers. But Howe was a man of remarkable perseverance and did not abandon his pet idea of supplying the United States with sewing machines. The theory of his machine was right but he failed to embody in it the proper mechanical forms to secure its commercial success. He was largely indebted to other men for the devices which made it a blessing to humanity. It must be remembered, however, that Howe's machine would actually sew. He had his first model on exhibition in a Boston clothing factory for a time and the demonstrations showed a capacity of 300 stitches a minute. He offered to sew any seams that were brought to him and did so in one-seventh of the time that the fastest sewers could do the same work by hand, and his work was conceded to be the neatest and strongest. But journeymen's enmity and other considerations kept all tailors from buying. Soon imitations of his sewing machine were made and sold to great advantage and the possibilities of the innovation began to be appreciated. Howe's patent proved to be well drawn, and the suits that followed left no shadow of doubt as to his rights. Royalties began to flow in and after the crucial suit against Singer was decided in 1854, the money value of his invention became fully apparent. In 1863 his royalties were $4000 a day, and it is estimated that they totaled over $2,000,000. In the course of the enormous amount of litigation that ensued in the sewing machine business, judicial decisions have affirmed again and again that no successful sewing machine has ever been made that does not contain some of the essential features of his first attempt.

The practicality of machine-sewing having been demonstrated, inventions and improvements of originality and merit followed in rapid succession. One of the most ingenious of inventors, and second only to Howe in the sewing machine field, was Allen B. Wilson. In 1849 he devised the rotary hook and bobbin combination forming the special feature of the Wheeler & Wilson machine. His patent of 1850 covered the invention of a moving feed-bar, having teeth projecting up through the horizontal cloth plate on the bed of the machine, in conjunction with a presser-foot coming down on the material to be sewed, thus presenting it for action by the feed-bar. His patents of 1851 and 1852, for an improved feeding device known as "the four-motion feed" for moving the work after each stitch and for a revolving hook for passing the upper thread around the bobbin containing the under thread, gave to the world a feed that admits the sewing of a curved seam, while the revolving hook is a marvelous piece of ingenuity and mechanical skill. The essential principles of his inventions are used in all the rotary hook machines of today.

The four-motion feed constitutes one of the greatest improvements that has been made in connection with sewing machines since Saint demonstrated that mechanical sewing was possible. Indeed, every sewing machine worthy of the name today incorporates this feature. Upon the cloth plate beside the point where the needle passes to penetrate the fabric, are one or two tiny serrated and moving surfaces. When a stitch has been formed these teeth rise a fraction of an inch to grip the surface of the material. Then it is moved forward the predetermined distance. This constitutes the second motion. The third motion is the descent of the teeth to release the fabric, followed immediately by the fourth motion, which is to move backward preparatory to rising to grip the material once more. By the introduction of this feature Wilson rendered the movement of the material not only automatic, instead of being moved by hand, but made the distance or movement of the material after each stitch positive and accurate.

The labor involved in sewing was appreciably decreased, as by this means it was only necessary to guide the work. The machine in which Wilson incorporated these features gained wide popularity.

In 1851 William O. Grover, a tailor of Boston, patented a double chain-stitch action which formed the basis of what was known as the Grover and Baker machine. In 1865 James A. E. Gibbs, a



From D. K. Clark's *The Exhibited Machinery of 1862*
THE ORIGINAL WHEELER & WILSON MACHINE

Virginia farmer, devised the single thread chain-stitch mechanism characteristic of the Gibbs & Baker machine, improved subsequently by J. Willcox and known as the Willcox & Gibbs machine. Yet, despite the activity of all these inventors between the years 1830 and 1851, the sewing machine had not met with complete favor. So many imperfect inventions were foisted upon the market to be proved unworkable that deep-rooted suspicion

THE GROVER & BAKER MACHINE

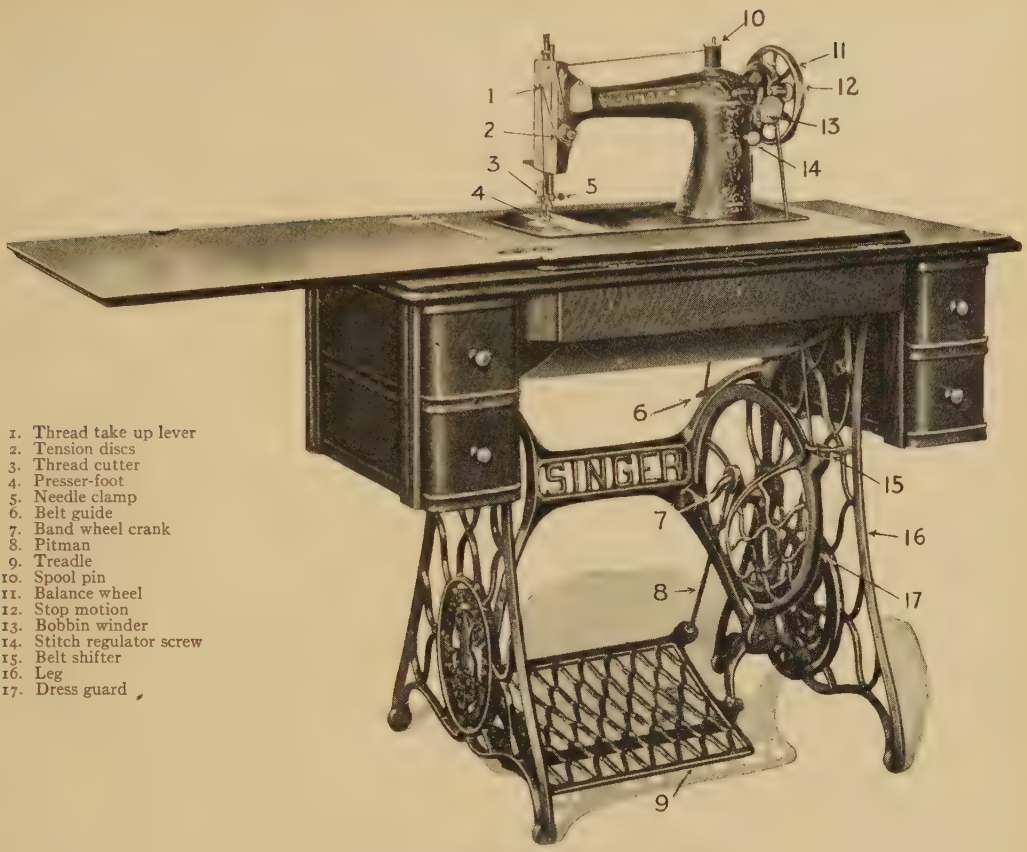
against every mechanical sewing device was aroused. This long-standing prejudice could not easily be overcome, and it required many years of patient effort on the part of the manufacturers to convince a skeptical public that each time an improved model was put on the market it was not another of the unsatisfactory machines which they were to be inveigled into purchasing.

But the sewing machine had now arrived at a stage when all its essential features had been invented and so far perfected as to demonstrate their practicability. It only remained for men of energy and business ability to further the work of manufacture and the development of facilities for marketing their product. Men who early appreciated the importance of the sewing machine as a factor in the commercial advancement of the world applied themselves with great zeal to the promotion of the industry. Factories were established in Bridgeport, Cambridge, Boston, New York and other cities for the exclusive manufacture of these machines. Bridgeport has always held a conspicuous place in the industry, and the history and development of the sewing machine will always be closely associated with that city. The importance of New York as a commercial center was early appreciated by sewing machine manufacturers, and it was made the principal sales depot for the industry by establishments located throughout New England.

The most prominent of manufacturers, if not of inventors, appeared in Isaac M. Singer, who came into the field in 1850. His first machine, patented in 1857, had a vertical needle movement driven by a rotary overhanging shaft, and a roughened feed wheel extended through a slot in the table. A yielding presser-foot alongside the needle held down the work. Motion was given to the needle-arm and shuttle by gearing. It used two threads and used the lock-stitch, the loop of the needle thread being interlocked at each downward movement by the thread of a reciprocating shuttle. Singer also introduced the rocking treadle to take the place of the hand crank for actuating the machine. But strange to say, although the treadle motion certainly constituted a distinctive characteristic used universally today, he neglected to cover his idea by a patent. It is thus seen that the patented features of his machine showed no wide departures from those of earlier inventors. It bore a close resemblance to Howe's but was vastly superior from the manufacturer's standpoint.

The Singer machines are remarkable from the fact that the earliest made were good working machines and successfully accomplished continuous stitching. The ground floor of sewing machine invention was established before Singer was attracted to the problem. It was too late for original dominant patents but his clear perception of the work of other men and his remarkable powers for the practical adaptation and utilization of his own and other's ideas placed him foremost in the manufacturing field. As soon as it became apparent that the Singer machine was succeeding, the proprietors had to defend themselves against attack under the patent of Elias Howe. Singer figured as the most obstinate defendant, on the strength of the earlier inventions of Hunt, but ultimately he, with all other makers became tributary to Elias Howe, and in 1855 took out a manufacturing license under the Howe patents. Singer was much discouraged at the decision against him. His dream had been to build a machine at a price easily in reach of the poorest needle-worker. But as long as Howe's patents held the cheap machine was rendered impossible. But assistance that enabled Singer to continue his efforts came from an unexpected quarter. His leading counsel, a Mr. Clark, suggested that if he were allotted a half interest in the invention he would finance it and convert it into a profitable enterprise. Clark was a man of energy, imagination and unbounded enthusiasm. He approved of Singer's great idea of introducing the sewing machine into every home. It was merely a question of organization and adequate financial resources, and the firm of I. M. Singer & Co. was founded. From that moment the future of the Singer sewing machine was assured.

The early Singer machines were designed principally for use in manufacturing operations, but when it became clearly demonstrated that the sewing machine would become an ordinary household instrument, modifications of the original machines were made, combining the substantial working qualities with lightness and delicacy of form and construction, to fit the



THE MODERN HOUSEHOLD SEWING MACHINE

light work of the family. The coming of Singer into the manufacturing field marked a new era in sewing mechanism. Through wonderful organization and the application of scientific principles of design the Singer Company has taken the lead in constantly introducing new and improved styles of machines for all conceivable purposes, though in the form and general structure they remain much the same as they originally were. The manufacture and sale of these machines have not been interrupted since they were first introduced and although there are many competitors in the field, for the basic patents expired about the year 1877, the Singer is still in the lead. In these and the other sewing machines of today three subordinate combinations of mechanisms are provided; a stitching mechanism, combined with appliances for maintaining the necessary degree of tension on the threads; holding surfaces for supporting the material against the thrust and withdrawal of the needle, at the part where the stitch is being formed; a self-acting and adjustable propelling mechanism for feeding the fabric along step by step, as each stitch is completed. Three varieties of stitch are made; the simple chain- or tambour-stitch; the double chain-stitch; and the lock-stitch. In the first variety the machine works with a single thread; the other forms use two, an upper and an under thread. Each has its adherents among seamstresses. The lock-stitch resembles weaving in its formation, while the chain-stitch resembles knitting and is easily raveled. It is estimated that about 90 per cent of the machines built for household use have the lock-stitch.

It will be seen that to make the lock-stitch the under thread has to be passed quite through the loop of the upper thread. That is done in two principal ways. By the first plan a small metal shuttle, hold-

ing within it a bobbin of thread, is carried backward and forward under the cloth plate, and at each forward movement passes through the upper thread loop formed by each succeeding stroke of the needle. Such is the principle devised by Hunt, introduced by Howe and improved by Singer and many others. The second principal method of forming the lock-stitch consists in seizing the loop of the upper thread by a rotating hook, expanding the loop and passing it around a stationary bobbin within which is wound the under thread. This method is the invention of A. B. Wilson, and is generally known as the Wheeler & Wilson principle.

Intermediate between the reciprocating shuttle and rotary hook machines is the oscillating-shuttle machine introduced by the Singer Company. The shuttle is hook-formed, not unlike the Wilson hook, and it carries within it a capacious circular bobbin of thread. The oscillating-shuttle and rotary-hook machines work with great smoothness and rapidity. It is thus evident that the basic mechanisms now in use for making the lock-stitch comprise a vertically moving bar carrying an eye-pointed needle for the upper thread, and either a vibrating shuttle or an oscillating or rotating hook for the lower thread taken from a bobbin.

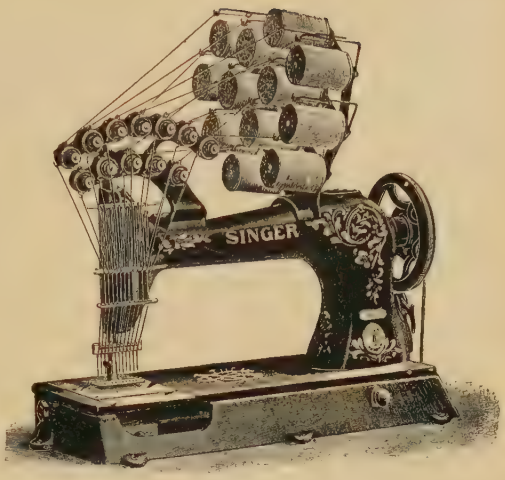
These together — all American inventions — form the types of the various machines now in common use. Thousands of patents have been issued in the United States and Europe covering improvements in the sewing machine; but, although its efficiency and usefulness have been greatly increased by numerous accessories and attachments, the main principle of the various machines has not been affected thereby. Even in its present high state of perfection, inventions are still numerous and patents are continually being granted. The same is true of the machinery for producing the various interchangeable parts of the sewing machine, the American principle of making all parts of the machine interchangeable having been carried to the fullest extent in this industry. The special machines for producing the more intricate parts of the sewing machine are so perfected that they perform their work with remarkable speed and accuracy, and often require more inventive talent in their construction than the sewing machine itself. In the leading factories the experimental department is one of the most important and expensive. Here the inventor has every facility for developing his ideas and putting the results to preliminary tests. Often a great deal of time and labor has been expended on the invention and development of a new part or attachment and it has been thoroughly tested in the department engaged in the manufacture of the class of work for which it is designed, and, if it proves satisfactory in operation, special machinery has been installed for its manufacture when some new discovery or improvement causes the invention to be abandoned. Though the inventor displays great originality and ingenuity in perfecting a device, the invention may have no value unless some equally talented mind is able to plan a way by which the invention can be made commercially available.

The manufacture of articles by the use of machines specially designed for the production of each component part, the various parts being subsequently assembled to form the finished product, was first carried out on a large scale in this country, and is still generally known throughout the world as the American system. With the advancement of mechanical art through the general use of machine tools, almost absolute precision in the execution of its processes was made possible. But the assembling system requires this perfect accuracy to be exactly uniform on each piece. In order to preserve a perfect uniformity of the dimensions of each corresponding part, it is necessary to use gages that shall test the truth of each, as compared with its standard to the most minute fraction. To no machine is this system more rigidly applied than in the case of the sewing machine. So highly perfected is this system that parts can be obtained from shops in every city of the world.

Many ingenious applications of the sewing machine to various kinds of work have

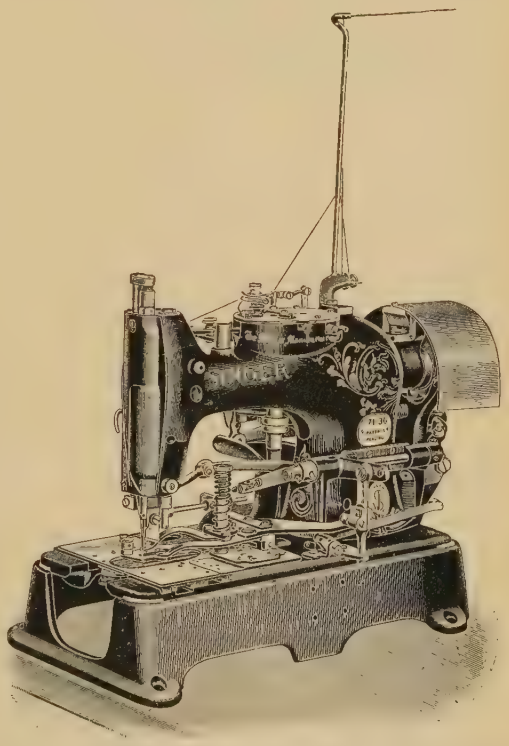
been made, and numerous attachments are supplied, so that its range is widely increased. Thus it is now possible to embroider, buttonhole, shirr, hem, tuck, darn, gather and do various other forms of sewing with facility on one machine, while in clothing and other factories special machines are adapted for various operations. Its sphere of use has been steadily and persistently extended until at the present time it is applicable to virtually every purpose where one piece of material has to be attached to another. The machines will cope with leather two inches in thickness as readily as two pieces of muslin. Nor are they confined to what might be termed straight sewing duties. They will make buttonholes at the rate of 10 to 15 a minute and even sew on buttons, though of course the design of the machine varies in detail according to the particular character of the duty which has to be fulfilled. It is even possible to equip the machine with more than one needle, the maximum in this direction being twelve needles set side by side to make an equal number of parallel rows of stitches, and each drawing its supply of thread from its own reel, so that various colored threads may be used at the same time. The total capacity of this machine is 9000 stitches per minute — 150 perfect lock-stitches every second.

With the special machines inexperienced operators can be taught in a day or two to stitch one particular part and in a few months will become more expert in doing that part than would an all-round operator, with years of experience, in doing a series of operations. This development of special stitching appliances for use in the factory has been not only of tremendous benefit to the world at large by causing a great reduction in the cost to the consumer, but it has brought commercial success to the manufacturer who could not have achieved modern results without these sewing machines. Manufacturers are constantly demanding a machine to perform some special duty or stitching process and this has resulted in the creation not only of hundreds of distinct types or classes of machines, but thousands of varieties or modifications of these classes



Multiple needle sewing machine for factory use for making two to twelve parallel rows of stitching at one operation.

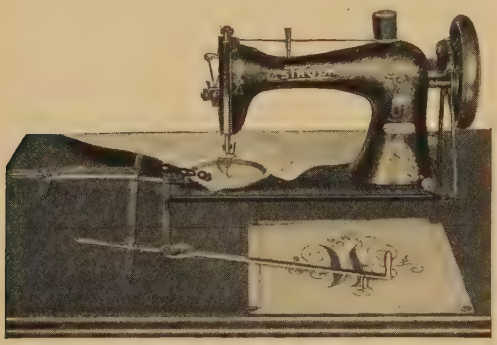
to meet special requirements. Some, for example, are capable of performing the most complicated operations in ornamental stitching; others are designed for use in great factories making gloves, shoes, harness, umbrellas and a great variety of work of a similar character. A recent



Modern buttonhole machine for automatically making straight buttonholes without eyelets purl- or whip-stitch in cotton and linen fabrics and knit-goods.

development is the automatic power carpet sewing machine, a compact little device which runs along the carpet and stitches together five yards of seam every minute, dispensing altogether with hand labor in this heaviest and most trying of all fabrics.

To the average person the making of a buttonhole may not seem of much importance, but when it is called to mind that the great clothing factories are confronted with many millions of buttonholes in collars, cuffs, shirts and shoes, the importance of reducing the enormous amount of hand labor is apparent. Several styles of buttonhole machines are now in use. The first of these, a crude device, was patented by Humphrey in 1862, but the



EMBROIDERY ATTACHMENT

In addition to regular and family sewing attachments are provided for embroidering initials, monograms, floral designs, etc., and for all kinds of hem-stitching.

Reece buttonhole machine, patented in 1881, brought the art of sewing buttonholes by machinery to its present state of perfection.

One of the most revolutionary of the applications of the sewing machine has been in connection with the boot and shoe industry. The McKay machine was invented in 1858 by Lyman R. Blake, and its numerous improvements have been remarkable in attesting to the ingenuity of the American inventor. It was developed by McKay and was the result of years of patient labor and of an expenditure of over $130,000 before practical results were attained. This machine was used extensively both in the United States and Europe, but it possessed the disadvantage that the shoes, though strong and comfortable when first made, could not be resoled except by pegging or nailing and had soles stiff and lacking in flexibility. In the Goodyear welt machine, which was first patented in 1871, a welt was sewed to an upper, and this welt in turn was fastened by an external row of stitches to the sole. Shoes made in this way were much more flexible and could be half-soled by the shoemaker by the ordinary process of hand-sewing. This remarkable machine was at once applied to the manufacture of fine boots and shoes and on it at the present time are made nearly all of the finer grades. In 1842 J. J. Greenough patented a machine for sewing leather and other heavy materials, but his machine did not come into general use. The following year George H. Corliss, the inventor of the Corliss engine, patented a similar machine which had two needles with eyes near their points, which worked horizontally through holes previously punctured by awls. The movements were derived from a cam mechanism, and the feed was automatic. Machines for sewing leather are now used in all branches of the leather industry, including the sewing of the uppers of shoes and the different kinds of stitching required for the manufacture of gloves, harness and saddlery.

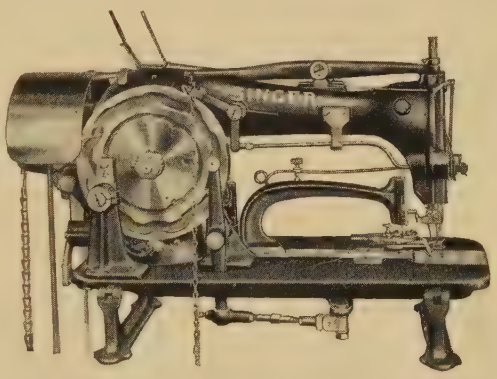
The sewing machines prior to Singer had no arrangement for applying power for driving them except the common hand crank. This required the right hand, so that only the left hand could be used for arranging and guiding the material to be sewed. Singer introduced the rocking treadle motion whereby the machine could be operated by foot-power. This was a great gain in utilizing the machine, but like some of his predecessors in the field, he did not realize that he had made an important discovery, and failed to apply for a patent.

Although Singer introduced the treadle in his very first machine, thereby releasing the hands for attention to the work, many ingenious efforts have been made to supersede the foot action. Of course, in large factories the machines are driven by power, but considerable ingenuity appears to have been displayed to adapt a power-drive to the single domestic appliance. During the first twenty years of the sewing ma-

chine's history after its introduction to commerce, numerous patents were granted for motors to fulfill this task. In the greater number dependence was placed upon the action of coiled steel springs demanding periodical winding in the manner of a clock. However, these fantastic conceptions failed to realize any profitable results for their ingenious creators. But the coming of electricity and its universal application brought about a far-reaching change. Today it is not difficult to render the home sewing machine independent of both hand and foot labor, provided electric current is available in the house. A small motor, developing about one-eighth horse-power, is mounted on top of or beneath the table, fed from an overhanging electric lamp or wall plug, and controlled by a switch, and the cost of operating in this manner is about the same as that of running a small electric lamp. The result is a higher sewing speed, averaging about 800 stitches per minute as compared with 200 to 400 stitches per minute with the foot. The stitching speed is controlled in an ingenious manner, merely depending upon the pressure exerted upon the treadle.

No greater testimony of the superiority of the American sewing machine could be demonstrated than its enormous foreign sale. In value of exports of sewing machines the United States leads the world. Great Britain leads all other countries as an importer, with Germany coming next. Our leading manufacturers have branch establishments abroad, where labor can be secured more cheaply than at home, and have them equipped with American machinery and tools for producing duplicates of the home product for the foreign markets. Some of these establishments are of immense proportions, their output surpassing that of the home plants. It has been estimated that the number of American sewing machines sold abroad each year, including the American machines made in foreign countries, is equal to the number disposed of in the home markets by all of the American concerns. The sales today exceed 2,000,000 machines per year, and it is estimated that the value of our total exports of sewing machines since the date of Howe's patent will aggregate nearly one hundred million dollars.

The greatest number of sewing machines sold are those designed for family use, and the largest number who require these machines are people without capital, who are not able to pay cash for their purchases. In order to follow the most direct method of placing their product in the hands of the consumer, the Singer Company in 1856 originated the system of selling sewing machines on the renting or installment plan, and this method has since been extended all over the world with remarkable success. Under this system the customer takes a machine and pays for it in installments from week to week, or month to month, often earning with the machine itself the money to defray the cost of its purchase. From the very beginning the idea caught the popular fancy. Branch offices were established in all the foremost cities of the United States, then the outlying towns had their representatives, and finally even the small villages were brought into the organization. It was quite a new way of conducting business, and the customers appreciated the system of direct selling because, aside from the convenience of the terms of payment, they were relieved of the anxiety and delay when accessories or new parts were required, and when a decisive improvement involved the bringing out of a new model, advantageous terms were offered to allow customers to acquire the latest machine in exchange for an old one.



MACHINE FOR ATTACHING BUTTONS TO CLOTHING
By means of an ingenious mechanism the needle is made to enter the button hole with great precision and the machine automatically stops when the button is sewn on.

BURMA — NATIVES OF THE JUNGLE, SOME 100 MILES FROM PAKOKKU

The naked Indian has bought the machine for his sister, who is sitting at it.

PHILIPPINES — AN IGOROTI FAMILY

The boy (16) is husband of the girl (14) for whom he has bought the machine. The children are her brother and sister, and the woman standing is a native teacher.

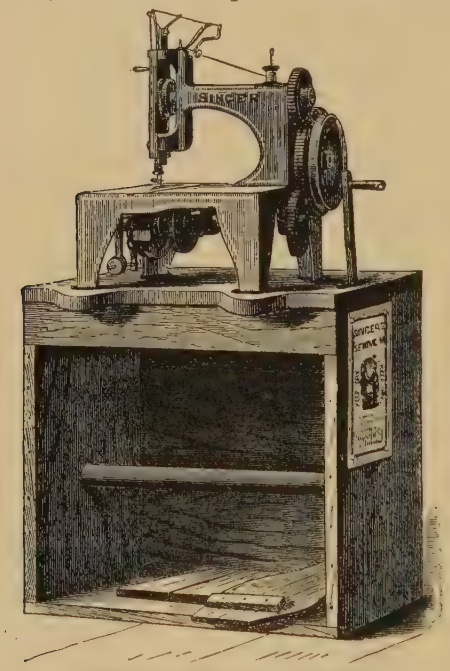
DISTRIBUTION OF THIS LABOR-SAVING DEVICE

CHILE — A MAPUCHE INDIAN FAMILY

Note the method of weaving employed by the grandmother in three generations represented in this hut in southern Chile.

ORANGE FREE STATE — NATIVE AFRICANS

The system proved so successful that by 1863, seven years after its inauguration, the sales had risen to 21,000 machines annually, in 1867 to 42,000, while during the next four years the output increased by such leaps and bounds as to reach the figure of 181,600 machines for 1871. A new company — the two original partners having retired with large fortunes — extended its sphere of operations to all the countries of the world. The Chinaman residing on the borders of Tibet, the peasant in the Caucasus, the lonely shack-dweller upon the borders of the Arctic Circle, is able to acquire the sewing machine on the hire-purchase system with the facility of the housewife residing in New York, London or Paris. The Singer Sewing Machine Company recognizes no distinction between nations, and no geographical boundaries. It pushes its way to wherever there is an opening for its activities. The company maintains over 8000 branches scattered throughout the world. Each country carries its distinct organization, formed in accordance with the laws of the country in which it is engaged in business, and when exigencies require it, establishes its local factory.



THE FIRST SINGER MACHINE

The first machines sold were intended to be set up on the packing cases in which they were transported; a rough wooden pitman connected the treadle to the geared balance wheel. A poster advertising the merits of the machine was pasted on the outside of the packing case, which thus constituted the first Singer cabinet.

The parent factory is at Elizabeth, New Jersey, but it has been exceeded in dimensions by one of its own family. The Singer factory at Clydebank, Scotland, ranks as the largest establishment in the world devoted to the manufacture of sewing machines. In normal times its payroll includes 14,000 employees. The company owns vast tracts of forests in this country whence all the lumber required for the Singer cabinet is derived, and its annual consumption of steel and other metal reaches an enormous figure.

The sewing machine companies have always shown great enterprise in bringing their product to the attention of the people. They have been tremendous advertisers, excelling even the piano and stove-makers in the unflagging zeal with which their inventions have been brought before the public eye. The newspapers, directories, fences, flagstaffs, the very rocks and trees, everything upon which a description of the merits of a sewing machine could be printed, posted or hung, have been pressed into service. County and state fairs, and the world's expositions here and abroad have been steadily frequented by these companies and their competitive displays have long formed the steady reliance of managers for one of the attractions of these bazaars of agriculture and industry. No machine has ever been so persistently canvassed and so extensively sold, and aided by the system of payment in installments there is scarcely a home today without its sewing machine.

But persistent exploitation does not alone account for this remarkably wide distribution. It has been due to the thorough, rapid and easy manner in which the machine has been made to perform its work. It has been simplified and improved to an amazing degree and its field of usefulness constantly broadened by the various attachments which have been successively devised for it. As a means of productive industry in the home no mechanical invention has ever approached the usefulness of the sewing machine.

THE REVOLT OF LABOR

Industrial Unionism Here to Stay
And a Power to be Reckoned With

ANARCHISM VERSUS SOCIAL REFORM

IN recent years the world has been startled by the spread of a new and revolutionary labor agitation, accompanied by a series of outbreaks of unprecedented violence, amounting in some cases almost to civil war. Like so many social movements, this first reached considerable proportions in France. In the summer of 1910 the railway system of that republic was tied up by a great strike of the employees. In connection with it an entirely new form of unionist action made its appearance. Telegraph lines and signal wires were cut and trains wrecked in addition to other less sinister interferences with the traffic. An astounding disregard for all recognized principles of action, even for human life itself, was shown. The strike was finally terminated by the Premier, Aristide Briand, himself a radical socialist, who called the men to the colors and, after promising concessions to their demands, ordered them to their tasks as military duties. Under these conditions refusal would have been mutiny, legally punishable with death. By an almost romantic coincidence, Briand, in a speech to laboring men made some ten years before, had mentioned the possibility of the government's using this device, had exhorted the men to pay no attention to it, even hinting at using their weapons against the government officials. Now he himself was the responsible agent of the government forced to employ it. The method was successful in his hands, but the men were bitter and did much damage to the railway system after returning to work.

More spectacular even than the French railway troubles was the series of strikes in Great Britain shortly afterward.

In the summer of 1911 strikes by the seamen and then by the dockers proved relatively successful and incited the railway men to imitation. That the industrial life of England, the world model for conservatism and orderly development, should be interfered with by a labor revolt, was unprecedented. Yet it occurred. Action was startlingly sudden; demands for recognition of the unions and for other concessions were presented to the railway heads and refused; the strike was called almost at once and so general was the response that within twenty-four hours business over a large part of the kingdom was at a standstill. Government intervention was at first sullenly rejected, but Mr. Lloyd George finally succeeded, by a combination of coaxing and bullying, in settling the strike, the men getting the best of the bargain and in particular securing the coveted recognition for their unions. The next year a similar and even more stubborn tie-up occurred in the coal-mining industry.

In most of the leading countries of the world similar events have taken place. Society has been brought face to face with strikes not aimed to coerce a particular employer into giving better terms to his workers, but designed to paralyze industry and throttle the whole social life. Many of these are peaceful, but others have been accompanied by almost revolutionary outbreaks of violence. Within a few years, besides France and England, Italy, Spain, Holland, Belgium and Sweden have had their visitations. In our own country the events are still so recent that we need merely mention them here. Class consciousness generally came late to the American work-

ing class, because of the extraordinary freedom of opportunity in a new country with vast areas of free land and nearly unlimited natural resources of every kind to be developed. But the time when the way to independence and proprietorship, and even to wealth and industrial leadership, was open to any man of ability is past; only by an exceptional combination of special endowments and rare good luck can a laborer hope to be anything but a laborer, and at the same time our wage level tends to approach that of Europe. Class feeling naturally came earliest in remote regions entirely dominated by one industry, in which the line between employer and employee is rigidly drawn. In the mining camps of the West violent labor disputes developed quickly, as such names as Bisbee, Arizona, and Ludlow, Colorado, will call to mind.

Strikes verging on civil war partly result of new kind of labor agitation

The recent alarming changes which have aroused the country are in part the extension of such occurrences to the older thickly settled parts of the country and to ordinary manufacturing industries, and partly the preaching of a new sort of labor agitation and working-class philosophy. Not only in the field of mining have we had strikes of the type verging on civil war, such as the Calumet copper strike in Michigan, the Paint Creek and Cabin Creek troubles and the Mingo County "war" in West Virginia, and the frightful slaughter in the Colorado coal mines. The greatest excitement has been caused by the appearance in the Eastern cities and in old established industries like the textiles, of a new type of labor organization and tactics. First in connection with the strike of the woolen mill operatives in Lawrence, Massachusetts, in 1912, and again in the silk mill strike at Paterson, New Jersey, in 1913, that part of the country was made familiar with such new terms and slogans as "I.W.W.", "syndicalism", "sabotage" and "class war" as a labor union policy. The Industrial Workers of the World, or I.W.W., is a labor union of a new kind and with new aims, organized at Chicago in 1905 around the Western Federation of Miners as its principal nucleus.

Rise of the I.W.W. movement, its high tide and recession

The I.W.W. had expanded by 1917 to include 30,000 members among the lumber workers, 40,000 iron miners, 24,000 agricultural workers, 15,000 in construction projects, and 10,000 in a "General Recruiting Union". This represents the high-tide of the movement thus far, for following the entry of our country into the war, it encountered a vigorous and unrelenting opposition. Many of its members were prosecuted under the Espionage Act and deported under the war Immigration Act, and cases of direct mob action are not wanting. In its eleventh annual convention in 1919 the organization reaffirmed its belief in the class struggle, and revolutionary methods of reform, expressed its approval of the bolshevik revolution in Russia, and addressed the industrial proletariat thus: "Workers of the world, unite! you have only your chains to lose. You have the world and life to gain. . . ." It represents the transfer to America of ideals and policies evolved by the working classes of other countries. To understand the new developments here we must glance briefly at the background of the division of society into working class and employing class and the struggle between the two.

How civilization, past and present, has been based on various forms of slavery

From the earliest days when anything that could be called civilization was in existence, it appears to have rested on a division of society into workers and those who enjoy the fruits of labor without themselves working in the narrow meaning of the term. Even in savage tribes we find that such arts as exist are carried on by the women, while the men act as rulers and protectors, or fighters, or engage in the chase. Perhaps they may be said to work, if the term is loosely enough taken, as no doubt the modern gentleman of leisure regards his activities as essential to the well-being of society; but in any case there is and has ever been a pronounced inequality in the distribution of the harder and more monotonous forms of toil on which the world lives.

As a matter of fact, the inequality has generally been of a most extreme character. Above savagery we find all early civilizations based on slavery, and that of an utterly ruthless sort. Slavery gave place to serfdom or was abolished only in recent historic times. And today we still have perhaps as great inequality as ever. The great masses of the people are forced to toil constantly and to live on very narrow margins, while a few live in luxury. Indeed, industrialism has been characterized as the most efficient form of slavery.

Under these conditions, it is but natural for those who have received the worst of the bargain to be dissatisfied with the existing state of affairs, and to strive to better themselves. This is what we find happening throughout history, from the slave uprisings of the ancient world to the mob violence of the modern strike. The laboring class has always been overwhelmingly superior in numbers; its weakness is in its lack of organization, which, again, is largely a matter of ignorance. Through this deficiency it has been kept in subjection, and until recently the ruling classes have been very careful to preserve the disorganized condition. In the last century, however, a change has taken place. Partly because the new era in industry which was inaugurated by the industrial revolution called for an educated working force, and partly because it gave rise to a great wave of humanitarianism, the right of the workers to an education and to combine for mutual aid has been recognized. Also, they have obtained a voice — in America early, and now in most of the nations, an equal voice — in the government. The reliance of the governing and property-owning class for maintaining its position came to be the inherent difficulty of organization on the part of laborers and its own power to convince them that the present private-property régime is just and to the interest of society as a whole.

The struggle of the workingmen to combine effectively and to agree upon and carry out a consistent policy makes up the history of unionism, which is too long a story to be told here. It was mainly fought out in England, which was for long the most advanced industrial nation, but the final result is not greatly different in the different countries of European civilization. The great weapon of the unions has always been the strike, or attempt to force an employer to terms by a concerted cessation of work which would cripple his business. Recently this tends to change into an effort to coerce society at large into coercing the employer in order to avoid great hardship to itself. The efficiency of the strike as a means of raising wages is uncertain.

A MASS MEETING OF STRIKERS IN THE SUMMER OF 1911

Wages have risen during the period, and in some cases advances have been won, or hastened, by strikes and threats to strike. But they have risen also in unorganized kinds of work and the total effect of organization in raising wages cannot be estimated.

What is certain, however, is that a strike results in enormous losses on both sides, and both soon come to recognize the desirability of avoiding the actual tie-up. It is obviously better to reach the same result by peaceable means, if it can be determined in advance what the result of the appeal to force would be. Hence the actual resort to striking came to be less common as the unions and employers learned their own and each other's power, and was replaced in large part by "collective bargaining". In this process each side makes a display of its needs and its power and the terms are settled by negotiation between representatives of the employers as a group and oftentimes the employers of a whole region collectively as well.

Other nineteenth century working-class gospels: socialism and anarchism

Unionism, however, was only one of many working-class movements which have been going on since the industrial revolution. The first half of the nineteenth century was very prolific in "utopias" or schemes for ideal societies in which the workers should be freed from the worst aspects of their toil and all men be on a plane of approximate equality. About the middle of the century, Bakunin and Proudhon gave a great impetus to the gospel of anarchism. Its general position is that the great enemy of the worker is the political state, which protects the capitalist employer in his position as exploiter, and that the remedy is to destroy all forms of government. It is argued that government is made necessary by the existing inequalities and injustices and that if these were done away with, men would have no inducement to prey upon each other and all political force could be dispensed with. We need not pause to criticize this doctrine, whose advocates have often been persons of the highest ideals, whatever we may think of their practical sense. Many anarchists, however, have held that government is an evil so great that any method of combating it is justifiable, and so have advocated violence and assassination of rulers and the like. President McKinley was murdered by one of these misguided fanatics. On the whole, anarchism has never made a very wide appeal or had any great measure of power and influence.

About the same time as the anarchistic movement, the modern form of socialism was being launched by Karl Marx and Friedrich Engels, the ground having been partly prepared for it in Germany by Ferdinand Lasalle. Socialism is often confused with anarchism, but is essentially its opposite. The two propagandas came into conflict in the International Society of Workingmen, and the anarchists were expelled. As we have indicated in the previous chapter, socialism stands for an all-powerful state which should conduct the industries of society and distribute the burdens and rewards in accordance with ethical principles. One of the main doctrines of the socialists was that of a perpetual "class struggle" between the proletarian and the bourgeois or capitalist classes. They became a political party, and as everyone knows have grown by enormous strides in the great nations, particularly in Germany and France where they have coöperated with the strong labor unions, as has also been the case to some extent in the United States.

How laborers have lost faith in unionism of the old sort and in political action

Thus of the three great labor movements, unionism and socialism were developing steadily hand in hand, one in the economic and the other in the political field, while anarchism ceased to be of importance.

But in recent times changes have been taking place which led many of the more radical working men to become greatly dissatisfied with the progress which was being made and to cast about for new methods by which to achieve results more quickly. In the first place, a rapid rise in the cost of living has set in which more than offsets the advances in wages which the workers could secure by the old methods, and has actually been eating away the ground already gained.

The "real wages" of labor, or the amount of commodities purchasable with a day's or week's earnings, had been going backward since about the opening of the present century until the war boom in industry raised the level in some lines though not much on the whole. Several causes have contributed to this result, but the principal one is undoubtedly the great increase in the world's supply of gold. Since gold is our standard of value, in which wages and all other payments are reckoned (a dollar is really just the command over a certain amount, 23.22 grains, of gold), a cheapening of gold is the same thing as a rise in prices. Thus, though the laborer may get higher money wages from year to year, he is receiving less value or purchasing power. The competitive market for labor is so much less sensitive than that for commodities in general that wages move up more slowly than the cost of living and the wage-earning classes suffer. More drastic measures for pushing up wages had to be found if the old standards of living were to be maintained.

At the same time, industrial changes were taking place which made the existing form of unionism less effective as a means of bargaining with employers. As a matter of historical necessity workingmen had organized by crafts; that is, men working at the same trade had united into locals and these had been grouped into city and state unions, etc. The majority of the labor bodies in this country had become affiliated with the American Federation of Labor, a national organization covering all trades and occupations, but without a great deal of power on account of the diversity of interests it is called upon to harmonize. The organization by crafts developed two fundamental defects. First, an effective strike generally requires that a large proportion of the men of all occupations in any establishment shall act together. With the different crafts bargaining separately, certain ones can be played off against others, and their power is greatly lessened. The employer can replace one kind of workmen, constituting a small fraction of his force, if the rest remain loyal.

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STEEL WORKERS IN PITTSBURGH LISTENING TO A LEADER'S STRIKE TALK

Some 350,000 operatives were involved in a possible nation-wide tying-up of the industry, one of the biggest strikes ever threatened in the United States.

Unskilled labor, generally poor and ignorant, harder to organize than skilled

Worse still is the situation in regard to unskilled labor. With the progressive specialization of occupations and increasing use of automatic machinery, it becomes easier to train a workman to fill nearly any place in a factory in a fairly satisfactory way. The range of skill required is small, and a few routine operations can be readily taught. Thus the unskilled laborer comes more and more to hold the balance of power in industry. But under the craft union system the unskilled laborers had never been successfully organized at all. Hence as the most necessitous of all, they furnished an unlimited supply of strike-breakers ready to the employer's hand. It was necessary to correlate the different crafts so that all in an establishment could strike together or bargain together, and also to include the unskilled laborer in the arrangement. The latter aim is especially difficult of achievement. Unskilled laborers are generally ignorant, have little money to pay union dues, and move about and change occupations a great deal. Moreover, they are more numerous than the skilled craftsmen, and on a basis of equal representation could out-vote the latter and control any union into which they had been admitted, a possibility to which the trained and highly paid workmen naturally object.

Labor and socialist members of national legislatures not so effective as hoped

The results of political action have also proven very disappointing to the high hopes of the advocates of this policy. In several countries, especially Germany and France, and more recently in England, socialist or labor parties have come to elect large numbers of members to national legislatures. They have been able to secure many reforms. The English tax reforms, smallholdings acts and municipal improvement measures, among other things, have attracted world-wide attention. In Germany, the cities and the general government have carried on very effective campaigns against the worst poverty, and the German workingmen's insurance laws have set a model for the world. The oligarchic government of Germany systematically set itself to undermine the radical labor movement by these measures. In France, too, the government undertook plans of social betterment to an extent which put the state in debt several billions of dollars in time of peace. But these achievements seemed small to those who had cherished the idea of a revolution that was to usher in a utopia, and they began to cast about for quicker methods. The result is the "new unionism".

"Syndicalism", cross between anarchism and socialism, which grew up in France

"Syndicalism", as used in France, is merely the name for unionism of any sort; the "new" or revolutionary unionism is there called "black" syndicalism to distinguish it from the old form or "yellow" syndicalism. But in England and America, the one word stands for the new movement. It combines the socialist doctrine of the class war with the anarchist ideal of a non-coercive organization from below upward, and its methods are those of labor unionism with an addition of anarchist violence. It is an outgrowth of unionism, but differs from the older form of the latter in its all-inclusiveness and in its revolutionary spirit. Instead of the organization by crafts, the unit is the industry, and one union is to include all the employees engaged in that industry, whatever kind of work they may perform. Thus a single union of railway employees, including all from engineer to track hands, will replace the separate unions of engineers, conductors, shopmen, etc. In particular, the unskilled workers are to be included, and put on an equality with the most highly trained. In order to do this, the dues are to be made merely nominal, and transference from one union to another easy.

The industrial plan of organization is not new; in fact, it was the original plan of the early unionists, but the difficulties in the way of such organization were greater than the more natural one by crafts, and the technique of administration had to be worked out in the latter first. The early industrial unions, such as the American Knights of Labor, disintegrated. With the

growth of the coöperative spirit, however, and better understanding of the defects of the craft organization, a movement of federation along industrial lines set in, and has made considerable progress in the American Federation of Labor. In France, the new unionists continue in their former organizations, promote the integration into industrial groups, and attempt to infuse their fellows with their revolutionary ideals. It is rather by accident that in this country they have started a separate and often competing union of their own, the I.W.W. Apparently the desire for quick results led the revolutionary leaders into taking a very unwise step from the standpoint of their ultimate aims.

The syndicalist ideal: "one big union" and no government

The syndicalist aim is in brief that of organizing producers into one big labor union, which will then take charge of the means of production and manage the system in the interest of the workers. Capitalism, wages and the competitive system will be done away with; there will be no place nor need for a government, in the political sense, and it will quietly cease to exist. Tasks will be apportioned and rewards distributed in accordance with abilities and needs, or some other principle, to be settled when the time comes. The details of organization of the big union are also expected to shape themselves to needs as they arise. The philosophy of the movement is that of action, rather than thinking things out in advance. Perhaps its popularity and the enthusiasm it arouses are largely due to this naïve way of passing over the difficulties of the scheme. On one thing, however, the syndicalist writers are agreed: the organization is to be of the nature of voluntary coöperation, with authority proceeding from the bottom upward, never the reverse. They vehemently repudiate the idea of a tyrannical, centralized state, however democratically constituted, such as orthodox socialism contemplates. Here the system shows its anarchist affiliations. It has been suggested that such a theory is in keeping with the typical form of French industry, which is still mainly of the small shop type and has not been concentrated in large establishments to the degree true of England and America. Our own syndicalists, the I.W.W., have a much more centralized organization, as would obviously be required by our more complicated industrial system. The older anarchism was also more popular in countries where the modern industrial development was less advanced. A "trustified" industry such as ours can be seen even by the blindest devotee of "liberty" to demand a large amount of control and an elaborate and efficient organization.

Syndicalist weapons: first, the general strike, through unionization of all workers

After the favoring of almost any sort of agitation, the next most important feature of syndicalism is the method advocated to bring about the changes proposed. In the minds of the new unionists, the capitalistic wage system is to be abolished and liberty and equality established mainly in two ways, through the general strike, and what is called direct action, the latter including a great variety of concrete proposals. The strike has always been the main weapon of the workers, and it is chiefly to employ it that unions have been organized. The syndicalist strike is a logical development of the former ideal, and differs from it as the new form of union differs from the old. The great weakness of the craft unions was in the small proportion of the employees of a plant included in any particular conflict. One craft could be played off against another, and, supplemented by unskilled labor, an establishment could generally be kept running and the strikers starved into submission. But if all classes and grades are in the same organization and walk out together, it will be much more difficult to replace them. If all workers are unionized on this system, it will obviously be impossible. Hence all that is necessary is to get the workers into the unions and make the latter capable of carrying on industry, and they can make their own terms or take possession of all the means of production and institute the new social system without delay. This would be the broad interpretation of the general strike, and is the

ultimate ideal. In the meantime, smaller strikes, as general in scope as possible, and preferably in the vital industries, such as transportation, will improve the conditions of the workers, keep up their fighting spirit to concert pitch, and whet their appetite for further victories.

Syndicalist weapons: second, direct action. The class war

Direct action, of which we hear so much in discussions of the new unionism, is a term loosely and vaguely used. It is primarily the opposite of political action, the aim of the socialists and the labor parties, and strictly taken would even include the strike. In the narrower sense, however, it stands for a general assortment of more or less violent measures, also a heritage from the anarchistic precedents of the movement. The syndicalists have taken over from the orthodox socialists the doctrine of the class struggle, which they translate into the class war, and give to it much of the meaning suggested by that strong term. They hold that workers and the employing classes are natural and implacable enemies, that no truce can ever exist between them, that no treaty is binding, and that in the struggle all methods, without distinction, are to be used. There is no right nor wrong in the ordinary sense; the only right is success, and failure the only wrong, and the test of the advisability of any procedure is whether it advances the aims of the working class.

In keeping with this view, the leaders advocate the policy called "sabotage", a French term derived from the word for a wooden shoe and meaning botched work. If the employers refuse to raise wages, the quality of the work must be reduced until he sees the error of his ways. Books and pamphlets have been distributed telling workingmen how most easily to spoil products and even to cripple machinery. Telegraph wires have been cut, trains held up or sent to the wrong destination by all sorts of deliberate "mistakes"; silks spotted by handling with greasy fingers; patrons of restaurants informed of the use of table leavings and adulterations in their food, and so on.

Some advocate ruining machinery with chemicals or by putting sand in the bearings, setting fire to property and the like, but it should be said that the more intelligent recognize the folly of extensive destruction. The doctrine of slacking or "soldiering", however, is generally believed in and often practised, and many claims are made for its success in bringing employers to terms.

The growth in prestige of labor during the Great War

The idealism engendered abroad and especially in the United States by the war proved a strong force in the advancement of labor generally. Labor union memberships increased greatly in all countries, material concessions were got through strikes and mere demands. Governmental agencies for dealing with labor were multiplied, new radical movements prospered, a third "International" was held, and a soviet republic supplanted the imperial government of a great European power. Of course, reaction from such advances is inevitable, but we may confidently expect that the general situation of the workingman will be bettered as a net result in the end, for that is the tale of the struggles of the rising proletariat in the last century.

In 1919 the American Federation of Labor counted 3,260,068 members as against 1,946,347 in 1915. In England from 1917 to 1919 membership in the trade unions increased from 3,082,352 to 4,532,085, the proportionate advance not being so large as in the United States because of the more extensive membership to begin with. In our own country this growth was accompanied by the extension of numbers in the I.W.W. to which we have already referred, and by the phenomenal growth of the Non-Partisan League in the Dakotas. In 1915 the farmers of North Dakota organized a political association to secure state ownership of terminal elevators, flour mills, packing houses, cold storage plants and state banks, and to exempt farm improvements from taxation. By the end of 1918 it mustered 188,000 members, chiefly in the Dakotas, Minnesota and Montana. In North Dakota, where the league was suc-

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STRIKING CLOAK AND SUIT MAKERS

This line, four deep, waiting to draw their weekly strike allowance of two dollars, extended for three city blocks and cost their union $80,000 every week that the strike lasted.

cessful in taking over the Republican party and obtaining control of the state government, the legislature proceeded to enact a number of laws carrying out the public ownership policy. This engendered intense opposition among the vested interests and those who regarded such a movement as the beginning of bolshevism in our country. Another political movement of some significance was the attempt to establish a political party in the United States comparable to the British Labor Party — one which should embrace orthodox socialists, trade unionists and intellectual liberals in a unified organization. However opportunely conceived, the project so far has shown little vitality, but a judgment now is impossible.

More relevant to the daily existence of the vast body of workers in the industrial East were the arrangements of our government regarding labor in the war period. The Wilson administration, while constrained by the emergencies of the situation to adopt many compromises, favored on the whole the adjustment of difficulties through the already existing channels of collective agreement and the use of arbitrary governmental authority only as a last resort. The National War Labor Board, created by a presidential proclamation, composed of ten members, five appointed by the A. F. of L. and five by a national producers' association, served as a voluntary supreme court to adjudicate labor disputes. Although its powers were extra-legal, in a number of instances its findings were enforced by the President under his war-time executive powers. The board generally accepted and enforced the principle of the minimum wage, eight-hour day, and the advancement of wages to meet the increased cost of living, and equal pay to women for equal tasks performed by men. Next to this body in importance came the Railway Labor Board, which, because of the government operation, held absolute control over the men involved in rail transport in the country. On May 25, 1918, it ordered an increase ranging from 43% on the lowest wages to nothing on the highest, and on April 10, 1919, a second increase was granted to engineers, firemen, conductors and brakemen. This board adopted a notably liberal policy with respect to accident insurance, old age pensions and the like. Besides these two departments the government instituted a Federal Employment Service which acted during the demobilization period and effected 3,778,808 placements.

The entrance of women into the war-time industries is of great significance in the general labor situation because it broke down many of the conventions which had excluded women from industrial activity of various sorts. If, as has become apparent, more and more of the tasks of the household are to be taken from the housewife by mechanical improvements and the extension of such devices as community laundries and kitchens, the economic strain thrust on the head of the family will inevitably force more and more women into gainful employment. In 1914, before the war broke out, 2,000,000 women earned a livelihood in industry while 1,650,000 worked in factories, but in 1917 the former figure had risen to 10,000,000 with 1,890,000 in the factories. Since then there has been a retrocession, and men have replaced many women workers. But the possibility of economic independence for women has at least been demonstrated.

While our own country witnessed a more general recognition of the importance of the claims of labor, the international labor movement was making great strides. The enthusiasm and idealism engendered in that time of great aspirations is best revealed in the statement of war aims adopted by the Inter-Allied Labor and Socialist Conference in London in 1918. The conference declared that militarism and capitalist imperialism were synonymous, that the international action necessary to the advancement of labor could only be secured by an effectual League of Nations, that territorial aggression by the great powers must be stopped. It urged the adoption of free trade generally, the prevention of monopoly in industry, and the formulation of plans for the reabsorption of men in the military service into industry before painful unemployment occurred. In its entire content the manifesto reveals an almost positive confidence that the time was at hand for labor to come to its own, that its demands could not be withstood, so potent had become the liberal reform sentiment among people generally, reinforced by a close and compact labor organization. Subsequently the International Socialist Conference at Berne (February, 1919), composed of representatives from virtually all countries including the Central powers, advocated disarmament and demanded the protection of small nationalities and self-determination for all peoples. The following month a conference was held in Moscow to organize a Third International. Inasmuch as the resolutions there adopted favored communism and the establishment of the dictatorship of the proletariat by direct action, the socialists of England and America repudi-

ated the entire affair while in other countries the movement was divided. The Third International was but the mutterings of the great giant Bolshevism which had risen in Russia two years before with such terror to the defenders of the *status quo*. The feature which was most disconcerting to these onlookers was the internationalism so intimately linked with the direct action program of the soviets. The workmen's fatherland is their class; their internationalism knows no boundaries. Capitalism is for them the only enemy to fight with. There can be little doubt that the actual accomplishment of a soviet republic in Russia has reflected upon the workers of our own country and given them something of prestige which they had not formerly.

The hope of the future: the gradual democratization of industry

We may dismiss the concrete program of social revolution advanced by the syndicalists and bolsheviks as visionary and impossible; but two things we must recognize. The first is that industrial unionism is undoubtedly here to stay, that it will probably grow in strength and is already a power, for evil at least, which must be reckoned with. The English railroad strike of a few years ago and the more recent threats of the railway brotherhoods to tie up or own transportation systems have brought this fact home to the minds of all. The other important consideration is that there are a great many real evils in the capitalistic wage system in its present form, and that these ought to be and must be remedied or ameliorated. As the political system of the western world has been democratized in the last few centuries, its economic system must be similarly transformed. In an earlier day the king or feudal baron treated his realms as his private property and his subjects in much the same way. As a recent writer has pointed out, the present stage in industrial development corresponds to this state of affairs, and can no more be allowed to endure than its political analogue. The naïve assertions often made by employers that "there is nothing to arbitrate", or that their business is their own to hire or not to hire on such terms as they see fit, will soon be classed with the "I am the state" of Louis XIV. Private property, like all other social institutions, must justify itself by its social utility. Concentrated control we probably must have, in order to secure productive efficiency, but manager and subaltern alike must recognize that the control is to be in the interest of society, not of the manager personally alone. Many men of wealth already accept the view that they are trustees for the public, but even if everyone did so this would not be enough. Their trusteeship must be made a legal and responsible one, not left to their own discretion. Furthermore, the men who work at an industry and the public which it serves must be the ultimate determiners of its managers' policies, as the voter is of those of the political ruler in a democratic state. Some sort of machinery of representation must be devised which will combine administrative efficiency with responsiveness to the general will. The ends and the outlines of policy must be given by the ultimate sovereign; the means and the details will probably be left to individual managers who may be in a modified sense the "owners" of the material property, as now. This is a difficult problem; it is not yet by any means solved in the political arena, where we have been working at it for centuries. We cannot expect a quick and easy solution in the economic field, where we are just beginning to attack it and where it is perhaps inherently more difficult as well. On the other hand, it is a similar problem in both fields, and the lessons learned through the political struggle will be of great value in the new task. In any case it seems that in this direction only is there hope of emergence from the present confusion and of making society more like what our moral sense demands that it should be. Along this road we are already moving, and with a clearer view of the goal and of the nature of the task progress can undoubtedly be made much more rapid. In the realization of the great ideal of a more just and equal distribution of produce and of power, perhaps no agency, unless it is the political state, has so great a contribution to make as the labor unions.

A GREAT BIOLOGIST AND PHILOSOPHER

ERNST HEINRICH HAECKEL, NATURALIST, WHO, AS A PROFESSOR AT JENA, GAINED THE EAR OF THE SCIENTIFIC WORLD FOR ALL HE WROTE

NATURALISTS AND BIOLOGISTS IV

GALEN — A PHYSIOLOGIST AT THE DAWN OF CHRISTIANITY
SIR FRANCIS GALTON — FOUNDER OF THE SCIENCE OF EUGENICS
CARL GEGENBAUR — DISTINGUISHED GERMAN COMPARATIVE ANATOMIST
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GIOVANNI BATTISTA GRASSI — FAMOUS ITALIAN ENTOMOLOGIST
ASA GRAY — ORGANIZER OF SYSTEMATIC BOTANY IN AMERICA
ERNST HAECKEL — THE GERMAN APOSTLE OF DARWINISM

GALEN

A Physiologist at the Dawn of Christianity

GALEN, or Claudius Galenus, in the Latin form of his name, was born at Pergamus, in Mysia, of Greek parents, about 130 A.D. His father, a man of rare qualities, chose for his boy the profession of medicine, which he began to study when he was about sixteen. He studied in Smyrna, Corinth and Alexandria, and in 164 at length reached Rome, where he spent a great part of the rest of his life. He was physician to the emperor Marcus Aurelius, and afterwards to his worthless son Commodus.

An ardent student, he became first a pioneer in many points of medical theory and practice, and, second, the encyclopædic mind of his age in medical matters. All that was taught, written and supposed from Hippocrates onwards, he endeavored to reduce to order. He was an untiring writer, and his writings were by no means all medical. As a boy, Galen had been nourished upon the stern fare of the Stoic philosophy. He was greatly interested in logic, and wrote a special treatise on the fallacies of language.

Galen was not, however, a writer merely. He had great clinical success, and an unrivaled contemporary reputation, being called the "Wonder Worker", but his results must largely have been due to his prestige, and to what we nowadays call common sense. None knew better than he — none knew so well — that the very foundations of his art did not exist, and he set to work to make them.

Human anatomy scarcely existed in those days, but Galen devoted much time to the dissection of the bodies of animals, notably monkeys. He studied many of the higher vertebrates, including one elephant. Above all, he is to be ranked as an experimental physiologist. In his time the arteries — or "air-carriers", to translate the Greek — were supposed to carry air from the heart to the brain (where it was supposed to be cooled) and other parts of the body. Galen opened an artery in a living animal, and found that it contained not air but blood, though we call these blood-vessels "arteries" to this day. In the corpse, an artery is found to be empty, the blood having accumulated in the venous part of the circulation as the heart failed at death; hence the error of centuries.

Galen fully realized the wonder and significance of his physiological researches. He tells us that his treatise on the uses of the parts of the human body is really a hymn to the Deity. "I hold," he says, "that true piety is shown not in the sacrifice of hecatombs of bulls, but in studying myself to know, and in making known to others, the wisdom, the power, and the goodness of God."

The heart, said his contemporaries, is the seat of the soul — for a man lays his hand on his heart when he is referring to himself. Hence, also, as the propinquity of the windpipe to the heart shows, the voice comes from the heart. Galen, on the contrary, correctly stated the functions of the chest-wall, the larynx and the nerves of the chest-wall, in the production of the voice — a marvelous feat indeed.

"When I tell them this," he complains, "and add that all voluntary movement is produced by muscles controlled by nerves coming from the brain, they call me 'paradoxologos' — a teller of wonderful tales — and have no argument beyond the assertion that the windpipe is near the heart."

Galen's observation upon the so-called "arteries" was extremely valuable, and led him, for instance, to initiate the clinical study of disease by feeling the pulse. But his researches upon the functions of the nervous system were more valuable still. He discovered the relation between one side of the brain and the opposite side of the body; he discovered what the function of the brain is, indeed; and he knew that paralysis of the lower part of the body is produced by section or damage of the spinal cord. He is, indeed, the founder of nervous physiology. After all this, it seems almost a trifle that he should have been the first to understand the function of the kidneys.

But Galen was a physician, too. He not only studied function and methods of diagnosis, but also devoted much time to therapeutics by means of drugs, though his achievements in this regard were not so valuable as his discoveries in anatomy.

At this day we speak of "galena", and describe certain pharmaceutical preparations as "galenical". The methods of scientific inquiry, which we call "modern", and which some suppose Bacon to have first devised, were practised consistently by this amazing genius — a kind of aftermath of the great age of the Greek mind — throughout the whole range of his inquiries. His successors had only so to proceed, and long before the year 1000 men would have known far more of health and disease than was known in 1850. But the "thousand years of darkness", of which we are the victims today, were to follow.

Galen knew nothing of that. He went on with his work. Apparently he retired from practice, and he is said to have returned to his native town. It is uncertain whether he lived to the age of seventy or eighty, and opinion is divided as to whether or not he died in Sicily, but it is certain that he left an undying name.

SIR FRANCIS GALTON

The Founder of the Science of Eugenics

FRANCIS GALTON was born near Birmingham, England, on February 16, 1822, of Quaker ancestry. His mother was the eldest daughter of Erasmus Darwin. He himself was the youngest of a family of seven. He was a student at the Birmingham General Hospital, at King's College, London, and at Trinity College, Cambridge, graduating at last in 1844. The possession of ample means, which prevented him from ever qualifying in medicine and settling down to practice, enabled him to gratify his fondness for travel, and he was the first, or among the first, to explore the White Nile and Damaraland. For this he received the gold medal of the Royal Geographical Society. His popular "Art of Travel" (1855) went into many editions.

In 1853 Galton married, but this founder of eugenics left no children for posterity. His marriage introduced him to social life, which he enjoyed, though if ever the saying was true, "A chiel amang ye taking notes", it was true where he was. He used to count people's fidgets to measure their interest, using his own pulse, furtively felt, as a watch.

Soon he became connected with the British Association, which he served faithfully in many capacities, though he twice refused its presidency. The special branch of science to which he now turned his attention was meteorology, upon which he left his mark no less definitely than upon geography. His passion for recording and comparing observations led him to undertake the huge task of charting the weather on a really substantial scale; and in the course of these studies he discovered, named and defined the characters of the meteorological condition which he called the "anticyclone", and for which, owing to its pleasing character, the name of "halcyon" has since been proposed. He standardized the sextant; contrived his apparatus for testing clinical thermometers, tens of thousands of which are now annually tested by this means; and suggested and established the rating of watches and chronometers.

Sooner or later such a man was plainly destined to start the measurement of living beings. As early as 1865 he had shown that talent may be inherited, and was devising schemes for measuring it and its inheritance. In 1882 he suggested the establishment of anthropometric laboratories, and he established one at his own expense at the Health Exhibition of 1884. In order to study the limits of hearing, he invented "Galton's whistle", whereby the pitch of a note can be raised until it can be heard no more. This is in daily use by aurists. Here, in passing, he came across finger prints, because he wanted a novelty for a lecture. He put his usual thoroughness into this subject; and now, all the world over, criminals are identified, thanks to his work. Composite portraits came in with the study of criminals, and stereoscopic maps "happened" in his mind by similar mental processes.

A small fraction of the foregoing would suffice to make a great life-work for any man, but we have scarcely yet alluded to the most important matter of all. The following names of books indicate it: "Hereditary Genius" (1869); "English Men of Science" (1874); "Human Faculty" (1883); "Natural Inheritance" (1889). The tragedy is that, before this series of books was begun, Mendel's work had been already published, but Galton knew no more of its existence than did his cousin, Charles Darwin.

In 1883, in "Human Faculty", Galton introduced the word "eugenics"; and to this subject, after many years during which, for lack of encouragement, he left it alone, he devoted the last decade of his life. He had already experimentally disproved Darwin's theory of pangenesis; he had seen the fact of heredity in man; and finally, aided by an invitation from the newly formed Sociological Society in 1904, he initiated the public interest in eugenics. He lived to see eugenics societies founded, and to address one of them, to contribute to a eugenics review, and to found a eugenics laboratory. He died on January 18, 1911, and by his will founded and endowed the Francis Galton professorship of national eugenics in the University of London.

In his "Memoirs of My Life", which Galton published in 1908, and which must always rank as a model autobiography, the ardor, the candor, the humor, the delight in life, the humility, the humanity, the richness of mind, which were the natural attributes of this illustrious man, are stamped upon successive pages in a fashion which reveals the man himself to the life. This was the last of his many books; for though he once

SIR FRANCIS GALTON

conditionally promised to undertake a volume upon eugenics, he fought shy of the task later, but published a collection of his addresses on the subject.

CARL GEGENBAUR

Founder of Modern Comparative Anatomy

IT is a platitude to remark on the generally uneventful lives of men of letters and of science. If we are seeking to be thrilled we turn to the exploits of explorers, inventors and soldiers. If, on the other hand, our interest lies in the hard-won secrets of the universe rather than in the difficulties encountered in their revelation, we find the long even years in university and laboratory as incident to our subject as lions to the explorer and blood to the fighting man.

Carl Gegenbaur is no exception to the generality of scientists whose outward life holds none of the perils of a Nansen or a Lafayette. He was born at Würzburg, Bavaria, August 21, 1862, and, having passed through the gymnasium of his na-

tive town, matriculated in the university of the same place. That he was fortunate in his teachers is evident, for he studied under such men as Kölliker, Virchow, Leydig and Heinrich Müller, and from them gained a thorough grasp of the comparative method. His father was an official of good position, and because of his various assignments in Weissenburg in Middle Franconia, and Arnstein in the Rhön Mountains, amid these rural surroundings the boy developed a deep interest in nature.

After obtaining his doctor's degree from Würzburg University and completing his medical studies, he suffered a period of indecision. He did not wish to begin to practise but longed to become a naturalist and enter upon a university career. This indecision sent him wandering. He journeyed through northern Germany, he studied the marine animals of Heligoland, and then started off on a scientific journey to Italy and Sicily. After Switzerland and Italy had been traversed, he joined Kölliker and Heinrich Müller in Messina, and spent six months studying the wonderful sea-creatures of the region. A journey through Sicily, a lingering sojourn in Naples and Rome and northern Italy and the period of wandering was over. From that time until a few years before his death in 1903 his life was passed in the learned seclusion of university and laboratory. For fourteen years he labored in the University of Jena, though many attempts on the part of other universities were made to lure him from Thuringia. Of these years he writes in his autobiography, "Jena was for me in every respect a high school, in which I received knowledge in many directions, and everything which I have later accomplished had there its origin and gives me reason for lasting thanks."

At last after considerable hesitation, in 1873 he accepted the call to Heidelberg as successor to Arnold, for "it carried him to the South whence he had come". He found in Heidelberg everything he could wish — a limited course of instruction in a magnificently equipped university, and leisure for uninterrupted progressive scientific work.

He was a successful and popular teacher, for though not a brilliant speaker, he was clear and possessed the power of treating the theme of his lecture in the shortest compass. Possessed of a magnificent constitution and an iron will, with but little inclination for society, he was somewhat hard upon himself and upon others. His students either dreaded or loved him, for he was invariably quick to detect either slip-shod work or honest endeavor. Every day he visited those engaged in research work, and the more difficult the problem the kinder and more encouraging he became, though in its early stages he gave due warning that the work had to be fairly shouldered. "I approve of your problems," he would remark, "but don't imagine I am going to help you. When you have got into it we shall have something to talk about," and the resulting discussions and criticisms opened up new vistas to those who had come to the master to learn how to research. His appearance was imposing. Tall and dark with a powerful head set upon broad shoulders, he belonged to the well-known Bavarian type. His brown eyes were steady and searching and his speech direct. To strangers he was difficult of approach, for his nature was reserved and, on occasion, choleric.

During his "wander years" and early stay in Jena his attention was given chiefly to the Invertebrata, concerning which he published many papers on the cœlenterates, echinoderms, molluscs and tunicates. But the greatest interest was excited among anatomists when he turned his attention to the vertebrate skeleton, and in memoir after memoir — all beautifully illustrated — added to our knowledge of the vertebral column, the skull and the limb-girdles and limbs of Vertebrata.

In 1883 appeared a textbook of human anatomy, which in fifteen years reached its seventh edition, and in 1898 and in 1901 his crowning work the "*Vergleichende Anatomie der Wirbelthiere, mit Berücksichtigung der Wirbellosen*". His research and teaching and books have established the reputation of Carl Gegenbaur as the founder of modern comparative anatomy on the theory of descent.

THEODORE NICHOLAS GILL
Interpreter of Taxonomic Facts in Ichthyology

THEODORE NICHOLAS GILL was born in New York, March 21, 1837, and was a descendant of Nicholas Gill who was admiralty judge of Newfoundland in 1822. He attended private schools and received instruction from special tutors. As he grew to manhood he developed an interest in natural science and made a study especially of fishes, frequently visiting the markets along the river-fronts in New York for the purpose of examining the uncommon varieties received there. During the winter of 1857–58 he made a trip to the West Indies and collected shells and various specimens of natural history, afterwards working up the collection in the library of Mr. J. Carson Brevoort. In 1859 he visited Newfoundland to study its fauna and the following year prepared a report on the fishes of the northern boundary for the State Department.

In 1867 he went to Washington as professor of zoölogy (professor emeritus after 1910) at Columbian (now George Washington) University, with which institution he remained connected until his death. In Washington, Gill came under the influence of Spencer F. Baird, who was quick to recognize his ability, and found congenial work for him in the library of the Smithsonian Institution, of which he had charge from 1862 till 1866. When the library was transferred to the national collections in the Capitol he continued in that service until 1874, and was for a time assistant librarian of the Library of Congress. Thereafter he devoted his attention almost exclusively to studies in natural history, working largely in the libraries of the Smithsonian Institution and the U. S. National Museum.

Dr. Gill was the author of numerous works in systematic zoölogy and of hundreds of papers, the greatest number being on ichthyology. It has been said of him that he was the keenest interpreter of taxonomic facts yet known in the history of ichthyology. His papers touch almost every group and almost every phase of relation among fishes. His numerous suggestions for classification have been usually accepted in time by other authors and no one had a clearer conception than he of the necessity of orderly methods in nomenclature. Among the orders first defined by Gill are the Eventognathi, the Haplomi, the Xenomi and the group called the Teleocephali, which includes all the bony fishes except those which show eccentricities. As a scientific critic he gave valuable and valued help to many American scientists. While no monumental work is left to us from his pen, nevertheless in nearly every zoölogical work his name will be found in connection with the description, nomenclature or classification of the specimens under discussion. He wrote most of the volume on fishes, and much of that on mammals, in the "Standard Natural History"; the zoölogical portion of Johnson's Universal Cyclopedia and the zoölogical text of the Century and Standard Dictionaries were also prepared by him.

His contributions to science were recognized by honorary elections to more than seventy-five scientific societies.

Dr. Gill died in Washington on September 25, 1914.

GEORGE BROWN GOODE
Discoverer of the Mystery of Deep-Sea Life

GEORGE BROWN GOODE, American ichthyologist, was born in New Albany, Indiana, on February 13, 1851, and died of pneumonia at Washington on September 6, 1896. He was of colonial descent, and he traced with pride his paternal line to John Goode, of Virginia, who came to that colony prior to 1660 and settled near Richmond.

In 1857 Goode's parents moved to Amenia, New York, where the boy was prepared for college. He graduated in 1870 from Wesleyan University, when he was only nineteen, and then studied under Agassiz at Harvard. From 1871 to 1877 he was curator of the Museum of Natural Science in Middletown, Connecticut, a work for which he showed great aptitude and which served as preparation for his reorganization of the National Museum in Washington later. Two important publications, "Museums of the Future" and "Principles of Museum Administration",

embody his views and experiences in this regard. His appreciation of the importance of such work is characteristically shown in his dedication of an interesting genus of deep-sea fishes to "Ulysses Aldrovandi, of Bologna, the founder of the first natural history museum". During the same period he was in the service of the newly organized United States Fish Commission, investigating and exploring along the Atlantic Coast.

In 1887 he became assistant secretary of the Smithsonian Institution, in charge of the National Museum; as such, and on

G. BROWN GOODE

account of his interest in museum administration, he was intrusted with a large amount of exposition work, which he always made a source of public education. He served as United States Commissioner in the Fisheries Exhibition held in Berlin in 1880, and in London in 1883, and was concerned in the Columbian Historical Exposition held in Madrid in 1892–93, where for part of the time he acted as Commissioner-General for the United States. His services in this connection were recognized by Spain by the conferment of the order of Isabella the Catholic, with the rank of Commander.

Goode was always deeply interested in the historical and biographical side of science, and in the personality, the hopes and the sorrows of those who preceded him in the study of fishes and other animals. This showed itself in sympathetic sketches of those who had to do with the beginnings of American science as well as with the dedication of new genera to those who had done good work in times when work was not easy and was little valued by the world. He was one of the founders of the American Historical Association, and a member of its executive council from 1889 till his death. In its first year he contributed to its *Proceedings* his valuable paper on the "Origin of the National Scientific and Educational Institutions of the United States". The organization and conduct of many other scientific societies owe much to his interest, for he regarded them as valuable agencies in the spread of scientific knowledge.

The most important of Dr. Goode's scientific studies had relation to the deep-sea fishes. In all this work he was associated with Dr. Bean, and the labors of many years were brought together in a splendid summary in two large quarto volumes — text and atlas — of all that is known of the fishes of the ocean depths and the open sea.

In this "Oceanic Ichthyology" he listed 156 new species of deep-sea fishes and 55 new genera belonging to the fauna of the Atlantic. The existence of definite large faunal areas in the deep seas was first recognized by Dr. Goode and has been carefully worked out by him. Perhaps the most popular of his works is his "American Fishes" (1888), a treatise on the game and food-fishes of North America, characterized by readableness and scientific accuracy.

Under his administration the influence of the National Museum was great in a degree far out of proportion to the sum of money expended, and with his death the world lost one of the most capable museum administrators.

GIOVANNI BATTISTA GRASSI

Famous Italian Entomologist

THE true value of a scientist's contribution to the world lies not in the great bulk of his work along the beaten track

but in the little amount of original discovery that he is able to make. Judged by this standard, Giovanni Battista Grassi's worth is considerable, for in no fewer than three branches of natural history his name stands for original attainment. In 1896, he was awarded the Darwin medal for his researches on the constitution of the colonies of the termites or white ants, and for his discoveries in regard to the development of the congers, murœnæ and common eels from Leptocephalus larvæ. Two years later, simultaneously with Bignami and Bastianelli, he independently proved the transmission of malaria to man by the *Anopheles* mosquito.

Grassi was born in 1855, and educated in Como and at the University of Pavia. He became professor of comparative anatomy in the University of Rome, and director of the Institute of Comparative Anatomy, and the state recognized his attainments by making him a senator of the kingdom of Italy.

Two species of termites or white ants are very common in Catania, and Grassi spent some years in a detailed examination of the nature of their colonies. At first he noted the usual characteristics of the communities; recognizing their division into both winged and wingless individuals, of which the winged, greatly in the majority, were divided up into two castes, the ordinary workers and the soldiers. With great interest the professor studied the abnormal development of the jaws of the soldiers, and comparing their size with the workers found some of them five times as large. Up to this point, his investigations only bore out what had already been discovered. When he examined in detail the bodies of the workers and soldiers — "neuters" or arrested males and females — he began to consider the question of the share which heredity plays in the development of the larvæ into kings or queens, soldiers or workers as the case may be. He found that the different forms in early life do not differ from one another, and are all equally endowed with the potentiality of the same instincts. Observing them very closely he was able to discover that their further development is ordered by the members of the colony, who administer different kinds of food to the various units according as the demand is for workers or soldiers, kings or queens.

Bearing on evolution, but having to do with widely different creatures, is his work on eels. Since the days of Aristotle, men have known that large eels pass from rivers into the sea at certain seasons, and that diminutive young eels ascend the rivers in enormous numbers. No one till the time of Grassi was able to say how the young eels were produced. He showed that, large as the eels are that pass into the sea, they are not perfectly developed fish, but only attain maturity at a depth of 500 meters. In due time they breed, and from their eggs are hatched the young Leptocephali. These strange, colorless, transparent creatures, with blood destitute of red corpuscles, had hitherto been regarded as a special family of fishes. But the powerful currents prevailing in the Straits of Messina occasionally bring up to the surface the inhabitants of the depths of the sea, and Grassi was able to secure adult eels with fully developed sexual organs, and their larval progeny or Leptocephali. He kept some in an aquarium and to his joy the Leptocephali developed into young eels, and the mystery was at last cleared up.

Living in Italy, one of the homes of "*mal'aria*", Grassi was naturally interested in the work of identifying the parasite which conveyed the dreaded disease. Independently, he proved that malaria in man was due to the presence of a sporozoan which invades and destroys at a certain stage in its life history the red corpuscles of the blood. The sporozoites are developed in a mosquito (*Anopheles*) and are transferred from its salivary glands to man by its sting or proboscis. In proof of his theory, the professor succeeded in producing malaria in man by the application of a parasite-inhabited mosquito. Having fully demonstrated the danger of its prevalence, he was then largely instrumental in the usual preventive methods against attack, screening houses, draining marshes and burning vegetation, by which many districts in Italy were cleared of the scourge.

ASA GRAY

Organizer of Systematic Botany in America

ASA GRAY, the foremost American botanist, with a reputation in Europe as a man of science perhaps even greater than in his own country, was born in Sanquoit, Oneida County, New York, November 18, 1810. His father was a tanner and the boy began life by feeding the bark-mill and driving the horse that turned it. He had some country schooling, two years at the Clinton Grammar School and one at the Fairfield Academy, so that "his general education was brought to a close at a point that one might roughly estimate as about half through a good high school today". His father persuaded him to turn his education to immediate practical use and to begin the study of medicine in the Fairfield medical school (1826). He obtained his degree in 1831, and his interest in botany, aroused by the chance reading of the article "Botany" in Brewster's Edinburgh Encyclopedia, had already begun with the collection and identifying of plants in the spring of 1828. When Asa Gray became interested in the science, "the classification of plants — chiefly of flowering plants — was the whole of botany; and it remained so in America well through his long life. In a certain sense, North America was then virgin territory and its rich flora was awaiting discovery and description. Naturally this was the first duty of American botanists, and it was a task that bred enthusiasm, just as the discovery of a new country is more exciting than its cultivation." Gray, a man of vivid personality, alert and quick in body and mind, made an ideal investigator and systematizer, and he soon attracted the attention and obtained the friendship of Dr. John Torrey, then the leading American botanist, and they were intimately associated until the latter's death in 1873. Through Torrey's influence he was named in 1836 curator of the collections of the New York Lyceum of Natural History, and it is here that Gray's professional career as a botanist began. In this year his "Elements of Botany" appeared, to be followed by the remarkable series of textbooks which for many years dominated botanical instructions in the United States and which are marvels of clear, masterful presentation. His "How Plants Grow" (1858) and "How Plants Behave" (1872) helped to arouse a popular interest in botanical studies, but his most important work was his "Manual of the Botany of the Northern United States" (1847). Dr. Charles W. Eliot says of this: "This manual has passed through a large number of editions, is clear, accurate and compact to an extraordinary degree, and within its geographic limits is an indispensable book for the student of American botany."

Invited by Dr. Torrey to become joint author of the contemplated "Flora of North America", he threw himself with characteristic energy into the task, and the first two parts appeared in 1838 — about half the first volume — and the second volume in 1843. In working on the "Flora" he became impressed with the need of studying the North American plants in the great herbaria of Europe. Nearly all the earlier collections were sent to Europe for identification "and the subsequent determinations of American botanists were based upon descriptions often imperfect and ambiguous, with no opportunity of comparison with the types." Where incorrect determinations had been made they were often perpetuated and descriptions finally changed to suit the wrongly named plants. "In Gray's first work on the 'Flora' he discovered that many American plants were masquerading under false names, but to discover the real plant to which the name belonged could only be done by examining the type specimen. He felt no more of the 'Flora' should be published until these types had been examined."

With this end in view he made six trips to Europe, beginning in 1838, visiting all the great herbaria and putting the older described American plants upon a sure basis. In these excursions he entered into relations with the leading botanists of England and the Continent, his scientific colleagues, which continued with increasing intimacy until his death. He was for years the medium through which Americans kept in touch with European botany.

In 1842 Asa Gray accepted the Fisher professorship of natural history at Harvard, and here he made a great reputation as teacher, author and investigator, and Cambridge became the botanical center of America. Dr. Eliot says that "on his accession to this chair the university had no herbarium, no botanical library, few plants of any value, and but a small garden, which for lack of money had never been well stocked or well arranged. He soon brought together, chiefly by widespread exchanges, a valuable herbarium and library, and arranged the garden; and thereafter the development of these botanical resources was part of his regular labors. The herbarium soon became the largest and most valuable in America, and on account of the numerous type specimens it contains, it is likely to remain a collection of national importance. Nothing of what Gray did has been lost." His pupils came quickly to share his enthusiasm and to admire his apt and lucid style and his "rare faculty of conveying his own knowledge to others by felicitous and accurate description". He was a great teacher and a keen, but friendly critic.

Gray had published a paper on the distribution of plants ("Statistics of the Flora of the Northern United States") in 1856, and in 1859 one on the "Relation of the Japanese Flora to that of North America", in which the conclusions as to a former arctic connection were all the more remarkable since at that time the testimony from the boreal fossil flora were not all in. It was Gray's study of plant distribution that led to his intimate correspondence with Darwin and his expounding and defense of Darwinism in America. His scattered writings on the subject were gathered in a volume entitled "Darwiniana" (1876), which is an admirable commentary on the theory of natural selection.

In 1873 Gray retired from active teaching to devote himself to the "Synoptical Flora", and the studies connected with it. With the notable collections made by the transcontinental surveys, then just beginning, coming in to Torrey and Gray for determination, the "Flora of North America" had been found hopelessly out of date before half of it had appeared and its completion had been postponed. The "Synoptical Flora of North America" began where the old work left off and then again began to traverse the ground of the older publication, utilizing the vast collections of new material. This task Professor Gray did not live to complete. He had been president of the American Academy of Arts and Sciences from 1863 to 1873, and, in 1871, of the American Association for the Advancement of Science. He died full of honors, respected at home and abroad for his attainments and for his services, January 30, 1888.

ERNST HAECKEL
The German Apostle of Darwinism

ERNST HEINRICH HAECKEL was born at Potsdam on February 16, 1834, and was educated at Berlin and Würzburg under Johann Müller and Rudolf Virchow. At the early age of twenty-eight he was made professor of zoölogy at Jena, and he held that chair until his retirement in 1909. He died August 9, 1919.

When the young Haeckel was appointed to his chair, the "Origin of Species" had just been published. The ardent young German naturalist became a disciple of Darwin, and he, more than all others put together, was responsible for the spread of the idea of organic evolution in Germany. His writings on organic evolution and the ultimate problems of philosophy were very extensive. His "General Morphology" was published in 1866, and the "History of Creation" two years later. Dr. Merz says of these books that they "deserve to have assigned to them a prominent place in the history of the scientific thought of our age". Darwin's verdict was: "Professor Haeckel has made a great beginning, and shows us how classification will in the future be treated." Huxley, also, wrote as follows: "Whatever hesitation may not infrequently be felt by less daring minds in following Haeckel in many of his speculations, his attempt to systematize the doctrine of evolution, and to exhibit its influence as the central thought of modern biology, cannot fail to have a far-reaching influence on the progress of science."

Haeckel's central idea is what he calls the "law of biogenesis". His readers may suppose it to be his, but it is much older. He, however, used it for all that it is worth — and, as we now know, a great deal more. It asserted that the history of each individual is a recapitulation of the history of the race, and thus Haeckel constructed, especially from the evidence of individual development, a genealogical-tree table of all living organisms, showing their descent as thus inferred.

Our quotations from Darwin and Huxley suffice to suggest that Professor Haeckel was a bold writer. In fact, he was the advocate rather than the seeker for truth. His mind was filled with the splendor of the theory of organic evolution, and with the most unmitigated detestation of anyone who thought otherwise, especially in the name of religion. He felt that he *must* prove the case in which he so earnestly believed as containing everything necessary for human salvation as he understood it; and the ingenuous reader is apt to pass from the realm of fact to that of speculation, in this author's company, without any consciousness of the hazard incurred.

No doubt the doctrine of organic evolution needed all possible help. It was in a tiny minority, and all established things were against it. Haeckel was a magnificently endowed champion, and his services can never be forgotten. He saw the living world, animal and vegetable, as a whole, and tried to bring the history of plants into line and order with that of animals. Every kind of argument was necessary for his purpose, and thus he never rejected the views of Lamarck in order to advocate those especially associated with the name of Darwin. He thus avoided the errors of the neo-Darwinians, and his writings gained in breadth proportionately.

An author so enthusiastic, so bold, so confident of his views even where no evidence existed, could not fail to be invaluable as a controversialist. Throughout the world for many years he was the acknowledged champion not merely of organic evolution, but of a thorough-going naturalism typically and utterly materialistic in every particular.

Darwin did not publish his views upon man until 1871, and three years later Haeckel was ready with his large work on the same general lines "*Anthropogenie*", of which a revised edition has been translated into English. More important still, from its influence upon the popular thought of our time, has been the "*Welträthsel*", or "Riddle of the Universe", which was published in 1899, and of which, in the original and in twenty-four translations, hundreds of thousands of copies have been sold.

In this extremely able and engrossing book the dogmatism and violence of the author's mind reached their height. The modest level of Huxley's "agnosticism" finds no counterpart here. This author does not assert himself to be one who does not know about the ultimate problems. On the contrary, he *does* know, and asserts the fact accordingly. Biology is left behind altogether — not merely the special departments of it which the author has studied at first-hand, but biology as a whole. The author passes into the realms of philosophy, and gives his conclusions there.

This is, of course, a perfectly legitimate process. Philosophy must be in accord with the facts of science; and the man of science ought not to be content until he has tried to make his facts fit into or serve towards the construction of a system of philosophy. But the methods which serve when a first-hand student is stating the facts of the embryology of some animal for the reader who has not studied them for himself are not necessarily adequate when the author employs them for the solution of the problems of the ages.

Professor Haeckel, as a philosopher, is not to be taken seriously, though he must have captured the minds of a vast host of young people throughout the world. Just as, in the dawn of Darwinian speculation, the young Haeckel was sure and went gayly ahead, where Darwin and Huxley knew that they knew nothing, and where later research has not justified him, so in his old age this remarkable man was sure of his answers to all the ultimate problems of the nature of life and matter, the origin and destiny of man and the universe.

COMPANIONS OF THE SUN

What Recent Observations Have Revealed Respecting Mercury and Venus

THE PLANETS INSIDE THE EARTH'S ORBIT

WE have already given some consideration to the vast cosmic processes by which our solar system is believed to have come into being. Let us now examine more closely the several planets and their satellites, the asteroids or minor planets, and the comets, meteorites and shooting stars, which also belong to the system, in order that we may return with more detailed knowledge to a brief review of their entire history. Knowledge of the individual planets has greatly increased within recent years, and has revealed a diversity which was previously quite unsuspected; yet that very diversity has done more than anything else to throw into relief the dynamic unity of the system and the orderly development of its individual members in accordance with fixed laws.

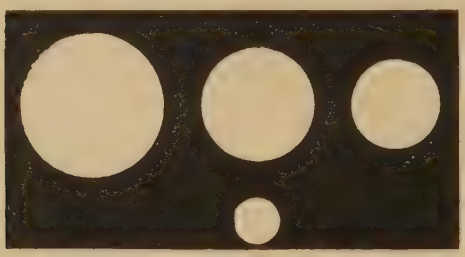
Mercury, the nearest of all the planets to the sun, is for that very reason not easily seen. Copernicus, the founder of modern astronomy, who was the first to lay down the principle that the earth and other planets revolve round the sun as their center, lamented before his death, in 1543, that he had never been able to catch a glimpse of this innermost planet. Probably the reason for his failure to see it is to be found in the nature of the district where he lived, the low and misty region of eastern Prussia, where the Vistula flows into the Baltic. Otherwise, one so deeply interested in the planets would certainly have seen Mercury at some time, because twice every year, in spring and in autumn, the planet is clearly visible for several days, appearing as a brilliant star of the first magnitude.

In spring it is seen early after sunset near where the sun has gone down, and must itself set within two hours after the sun. In autumn, on the other hand, it is a morning star, appearing as the forerunner of sunrise. Mercury has been known from the earliest times, and because of its appearance sometimes in the east and sometimes in the west, it was from the first very naturally regarded as two separate stars, a morning and an evening star, and was thus represented under two names in the mythologies of Egypt, India and Greece.

In spring, which is the more convenient season for us to watch it, Mercury is first observed very soon after sunset. Night after night, when the twilight deepens enough to show the stars, it is seen to appear higher in the sky, and night after night it increases in brilliancy. Then the contrary process sets in; night after night Mercury follows the sun more quickly over the horizon, and at the same time its luster diminishes. The course of its autumnal appearance as a morning star is closely similar; at first it is not very brilliant, and is seen very shortly before sunrise; then it gains in brightness and appears daily earlier before the sun; and then the process is reversed — it approaches the sun and becomes fainter day by day.

It is only to the unaided eye, however, that Mercury is thus invisible except in spring and autumn. By means of the telescope this planet, like other luminaries, can be seen all round the year, and high in the sky in broad daylight. The telescope shows also that the disc of Mer-

cury has phases like those of our moon, increasing from a thin crescent to a full circle, decreasing again to a crescent, and then disappearing altogether when the planet is nearly between the earth and the sun. Mercury and Venus, being within the earth's orbit, are alone among the planets in showing the full cycle of these phases; Mars periodically shows the gibbous phase like the moon a few days before or after full, but never becomes a crescent, and we see the discs of the other outer planets always fully illumined. The mean distance of Mercury from the sun is 36,000,000 miles; at perihelion, or the nearest point of its orbit to the sun, it is 28,500,000 miles away; and at aphelion, or the furthest point of the orbit, is 43,300,000 miles. Mercury has, therefore, an orbit which is far more elliptical than



SUN SEEN FROM MERCURY AND THE EARTH

The comparative sizes of the sun's disc, as seen from Mercury at its least, mean and greatest distances, and also (below) as seen from the earth.

that of the other planets, which are indeed elliptical, yet so slightly so as to be hardly, if at all, recognizable in a diagram.

The eccentricity of the orbit is so great that sometimes Mercury is only two-thirds as far from the sun as it is at other times. In consequence, the angular diameter of the sun's disc, as seen from Mercury, must vary greatly. As seen from earth the sun subtends an angle of 32′; but at the distance of Mercury the angular diameter varies from 67′ at aphelion to 104′ at perihelion. That is to say, the sun's disc as seen from Mercury has at least more than four times the area, and at most more than nine times the area, that it has when seen from earth; and consequently the heat received by Mercury must exceed from four to nine times that received, area for area, on the earth's surface.

Mercury completes its orbit in almost exactly 88 days, so that this planet runs through rather more than four of its years to one of ours. The velocity of its movement along its orbit varies considerably, according to its distance from the sun. Thus, Mercury travels at 23 miles per second at the remotest part of its orbit, but attains a speed of 35 miles per second where its path lies nearest to the sun. The mean velocity is 29 miles per second, and at that rate Mercury moves through the distance of its own diameter in about two minutes. The distance of Mercury from the earth varies from 50,000,000 miles, when the planet's disc has an apparent diameter of 13″, to 136,000,000 miles, when the diameter of the disc decreases to 4½″.

Mercury was long supposed to rotate upon its own axis about as fast as the earth does, and so to have a day of about twenty-four hours. But Schiaparelli, who was the first to undertake the systematic study of the planet during the hours of daylight, concluded from his extended observations of the markings on its surface that Mercury's day equals 88 of our days, and this conclusion was confirmed by Lowell's observations at Flagstaff. In the case of this planet, therefore, the day and the year are of equal length.

As our moon rotates once on its own axis in the course of its revolution round the earth, so that it keeps always the same face turned towards us, so Mercury always presents the same face to the sun. The cause of the fixed aspect is doubtless the same in both cases. The tides raised in Mercury by the gravitation of the sun have long ago by their friction brought to an end the planet's rotation relatively to the sun.

One hemisphere of Mercury is therefore exposed incessantly to the fierce heat of the sun; while the other hemisphere is forever exposed to the frigid night of outer space. Yet, as in the case of the moon, so there is in Mercury also a belt of land on either side, lying between the hemisphere of day and the hemisphere of night, where there are alternate day and night, sunrise and sunset.

WHERE THE SUN SHINES AT NIGHT AS WELL AS BY DAY

THE MIDNIGHT SUN OVER THE GLOCKENSUND

FACING PAGE 2712

This narrow belt, about $23\frac{1}{2}°$ in width, of changing light and darkness, is due to the highly eccentric form of the orbit. In order that the planet might keep always exactly the same face to the sun, while pursuing such an orbit, it would have to rotate at varying speeds upon its own axis, turning now somewhat slower and now somewhat faster. But the speed of its rotation being constant, its face is turned not always absolutely to the sun, but sways now slightly forward, along its orbit, and again slightly backward. The axis about which Mercury rotates is not inclined to the plane of its orbit, as in the case of the earth, but is vertical. The planet therefore has no seasons, except such as may be caused by the wide variation in the apparent size of the sun's disc we have already mentioned. Mercury has a diameter of about 3400 miles. It is not accompanied by any satellite.

The phases of the planet are not visible to the unaided eye; the telescope is needed to enlarge the brilliant point of light into an image of disc or crescent. With a powerful instrument and good atmospheric conditions, the terminator, or line separating the bright from the dark portion of Mercury's globe, is seen to be very irregular, as it is in the moon, showing that Mercury's surface, like hers, is highly mountainous.

Mercury shows no trace of an atmosphere, the bright and dark portions of the disc being sharply separated without any twilight. In this respect, as in others, Mercury resembles our moon in being a dead world. Its surface is closely comparable to that of the moon with regard to their respective power of reflecting light. As a reflector, Mercury is far inferior to Venus.

The markings on the face of Mercury were minutely studied by Lowell at Flagstaff, and, as mapped by him, they present a very definite and remarkably geometrical appearance. He suggested that "they seem to mark a globe sun-cracked. At such a condition the curious criss-cross of dark, irregular lines certainly hints, accentuated and perfected as it is by a bounding curve where the mean sunward side terminates. Though they cannot probably be actual cracks, however much they may resemble such, yet they may well owe their existence to that fundamental cause."

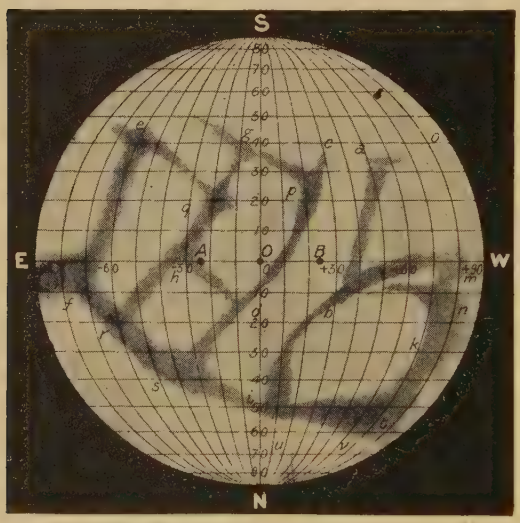
The transit of Mercury or of Venus is the passage of the planet between the earth and the sun, so as, from our point of view, to cross the face of the sun.

Of course, only these two planets, having orbits within that of the earth, can ever pass over the sun's disc. If Mercury's orbit were in the same plane as that of the earth there would be three transits in the year, because the inner planet revolves four times round the sun in a year, while the earth revolves once round the sun in the same direction. But the orbit of Mercury is inclined by about

MERCURY AS SEEN AT ITS GREATEST, MEAN AND NEARLY ITS LEAST DISTANCE

seven degrees to the ecliptic — that is to say, to the plane of the earth's orbit; and Mercury therefore crosses the ecliptic twice in eighty-eight days, but is usually either above or below that plane. A transit of Mercury can only take place when the planet is between the earth and the sun, and happens also to be crossing the ecliptic. These two conditions coincide from time to time at unequal periods, as follows — three years, ten years, three years, thirteen years, seven years, ten years — and then the same cycle recurs again and again indefinitely. Thus recent and coming transits of Mercury are in the years 1878, 1881, 1891, 1894, 1907, 1914 and 1924. All transits of Mercury are either in May or in November, the next two after the present date being those of May 7, 1924, and November 8, 1927.

The transit of Mercury was first foretold by Kepler, in 1627, for November 7, 1631; and a few hours after the moment which Kepler had predicted, Gassendi, the French philosopher and mathematician, watching an image of the sun projected into a dark room, saw the black globe of the planet entering upon the sun's disc. Since that date the transits of Mercury and of Venus have been carefully observed as astronomical events of the first importance. Their scientific value is manifold. They afford an opportunity of checking very exactly all calculations with regard to the orbits of these planets; special observations may be made of the dark planetary globes when silhouetted against the bril-



THE MARKINGS ON MERCURY

liant background of the sun's image; and the transit of Venus in particular has been used to determine the astronomical unit in terms of which all measurements of distance within the solar system are expressed.

Like Mercury, the planet Venus is at times an evening star, appearing after sunset, and at other times a morning star, appearing before sunrise, and was therefore known in antiquity under two names, Hesperus and Phosphorus. Like Mercury also, as an evening star it rises higher night after night, increasing in brilliancy, and then returns night after night towards the sun; and as a morning star it daily precedes the sunrise by a longer interval, and then daily this interval diminishes again. But its orbit is much larger than that of Mercury, so that Venus may rise as long as four hours before the sun, and set four hours after it.

After the sun and moon, Venus is by far the most brilliant luminary in the heavens. At its brightest it is more than fifty times as bright as any other star in our sky; it throws by night a distinct shadow; and by day, if one knows where to look for it, and the atmosphere is favorable, Venus may be seen with unaided vision in full daylight.

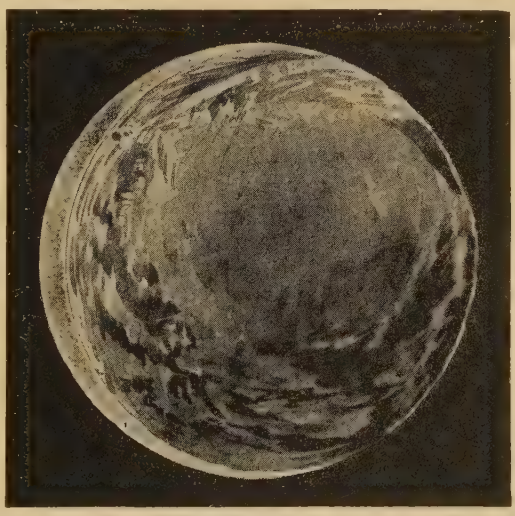
Being within the orbit of the earth, Venus has phases like those of Mercury and the moon. These phases are invisible to the unaided eye, to which the planet always appears as a point of light, but they may be seen with a telescope of no great power. They were among the first discoveries of the telescope, having been seen by Galileo in September, 1610. Anxious to secure the merit of the discovery without risking his reputation by publishing before he had made sure of it, Galileo sent out an anagram, the letters of which could be transposed into a Latin verse announcing the phases of Venus. The phases are best studied in daylight, because of the great brilliancy of the planet by night. Venus is very much larger when seen as a crescent in that part of its orbit which is near to earth than when seen as a full disc at the other side of its orbit. At its extreme distance the disc has an angular diameter of nine seconds, but at its nearest point the crescent has a diameter of over sixty seconds. This extraordinary variation in its apparent size is accounted for by the great difference between the distances from earth to Venus when the latter is at the nearest and at the furthest points of its orbit; when nearest to earth, Venus is 26,000,000 miles away, but when furthest it is at a distance of 160,000,000 miles.

The orbit of Venus is very nearly circular, and has almost no eccentricity. The planet revolves about the sun once in about 225 days — that is to say, in about seven and a half months. Venus is very nearly the same size as the earth, having a

diameter of 7575 miles as compared with earth's mean diameter of 7918 miles. The axis about which Venus itself rotates is almost vertical to the plane of its orbit. In the seventeenth and eighteenth centuries it was reported again and again that Venus had a satellite, but as no evidence of this moon has been seen with the far more powerful telescopes of later date, it is believed that these earlier accounts were due to imperfections of the instruments then in use, or to want of familiarity with certain optical illusions, or "ghosts", which are incidental to all telescopic observation.

The planet Venus has an atmosphere to which by far the greater part of its brilliancy is due. Evidences of this atmosphere are manifold. Thus twilight, which is always and everywhere due to atmosphere, is seen along the inner curve of the planet's crescent, and prolongs the points or cusps of the crescent beyond the semicircle. Spectroscopic examination of the planet's light shows the spectrum of sunlight, together with absorption lines due to its passage through an atmosphere which according to many astronomers does not apparently differ greatly from our own; the positive evidence, however, for this view is not conclusive and Drs. St. John and Nicholson of the Mount Wilson Observatory have recently shown from spectrograms of high dispersion that the layer of Venus' atmosphere penetrated by the sun's light before being reflected back to the earth contains not over one-five-hundredth part of the amount of oxygen, nor over one-fiftieth part of the amount of water vapor contained in our own atmosphere.

On the occasions of its transit, when Venus enters upon the sun's disc, the outer portion of its dark globe, which has not yet crossed the edge of the sun, is plainly outlined by a ring of light, due to refraction of the sunlight by means of the planet's atmosphere. From the extent to which it refracts light, it has been estimated that the atmosphere of Venus is nearly twice as dense as that of earth. But the most remarkable evidence of this atmosphere is shown when the planet approaches what is known as inferior conjunction — that is to say, the point of its orbit at which it is between the earth and the sun. If it should happen at the same time to be on the plane of the ecliptic, it will then, of course, cross the sun's disc, and be visible as a black globe. But in the great majority of cases, when Venus is in inferior conjunction, it is either above or below the ecliptic, and would thus be invisible, as the new moon is invisible, except for the presence of an atmosphere. When followed by the telescope to this position, the crescent of the diminishing Venus becomes narrower and narrower, and then flows right round the dark disc, so that the entire profile of the planet is outlined by a ring of sunlit atmosphere.



THE LIGHT WITHIN THE CRESCENT OF VENUS

Just as the unilluminated disc of the moon, usually invisible within its crescent, is often seen to gleam faintly with earth-reflected light, presenting the appearance known as "the old moon in the young moon's arms", so the dark portion of the disc of Venus sometimes shines dimly with a light which cannot be derived immediately from the sun, showing a pale, ashy gleam over all the surface which is embraced by the vivid silver of the crescent.

This appearance is not easily explained, but there is no lack of theories intended to explain it. Observing that this faint illumination of the night side of Venus has sometimes a violet tinge, and that

the years in which it has been most noticed have corresponded to some extent with those in which the aurora borealis has been exceptionally active on earth, some have persuaded themselves that we witness from time to time displays of the aurora in Venus. Others consider that the general light of the stars, reflected from the clouds and atmosphere of Venus, is sufficient to account for this ghostly glimmer. Others, have boldly suggested some kind of phosphorescence of the planet's surface. Newcomb pointed out that the phenomenon is only seen in the daytime or in bright twilight, and rarely or never after dark, and dismissed it as due to some unexplained optical illusion. "Such an illumination," he says, "would be far more easily seen by night than by day, because during the day an appearance easily seen at night might be effaced by the light of the sky. If, then, the phenomenon is real, why is it not seen when the circumstances are such that it should be most conspicuously visible?"

THE VARYING PHASES OF VENUS AND MERCURY

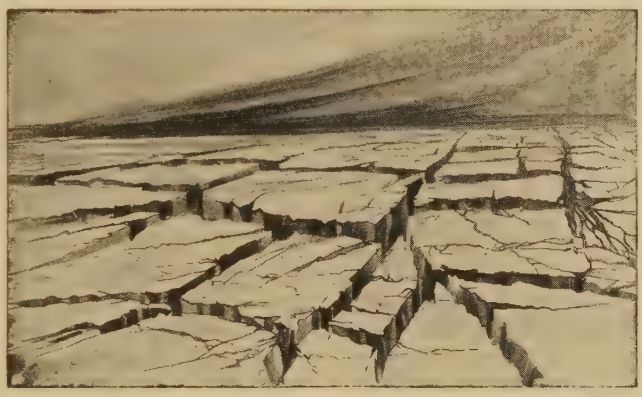
Lowell, believing for other reasons that the night side of Venus is covered with ice, applied that theory to explain its elusive glow. "If the night hemisphere of Venus," he suggests, "be one vast Polar sheet, we have there a substance able to mirror the stars to a ghostlike gleam which might be discernible even from our distant post." So we have free choice of conjectures in the matter.

The extraordinary brilliancy of the planet's illumined surface is more easily accounted for. Venus is so near the sun as to receive about twice the amount of light on its surface that we receive on earth; it is also near to the earth, so that the reflecting surface is large from its proximity. It is brightest when it has approached so near the earth that its illumined crescent occupies only one-fourth of the area of the disc. But the brightness of Venus is chiefly due to the nature of the reflecting surface. Area for area, Venus is five times as bright as Mercury, although Mercury is far nearer to the source of light.

It is estimated that Venus returns almost nine-tenths of the light which falls upon its surface, being thus an even more perfect reflector than white clouds, which reflect little more than seven-tenths of the light which they receive. This unusually effective reflecting surface is the planet's atmosphere. It was formerly believed that Venus was wrapped in an envelope of clouds, and that these gleamed in the sunlight with such brilliancy as to distinguish this planet above all other stars for brightness. But it is now known that, bright as they are, clouds are yet not nearly bright enough to give the reflected light which we receive from Venus.

It was believed until recent years that Venus rotated on its own axis in somewhat less than twenty-four hours, and this view was supported by observations which appeared to be very exact, though more recent study seems to overthrow them altogether. As early as the seventeenth century, Cassini distinguished a bright spot on the planet's surface, and, following its movements, concluded that the day of Venus was of nearly the same length as the terrestrial day. Towards the end of the eighteenth century Schröter came to a similar conclusion. He found that one of the points of the planet's crescent was blunted at intervals of rather more than twenty-three hours, and considered that this effect was due to the daily return of some mountainous elevation to that point.

Again, in the nineteenth century, the same period of rotation was affirmed by De Vico, on the basis of a study of certain markings which he thought he observed on the face of Venus, and their apparent daily movements. But many astronomers were never able to distinguish definite and permanent markings of any kind, and were inclined to agree with Herschel that Venus was wrapped in clouds which hid the features of the surface and prevented any trustworthy observations of its rotation. It is now fairly certain that both of these views were mistaken. Venus does not rotate in a way which is at all comparable to that of our earth, and the astronomers who witnessed that rotation were unconsciously influenced by what they expected to find. On the contrary, it is most probable that Venus, like Mercury, turns always the same face to the sun, its day being thus coextensive with its year. Nor is the atmosphere of Venus cloudy, but quite the contrary, it is brilliantly clear.



AN IMAGINARY LANDSCAPE ON THE SUNNY SIDE OF VENUS
It is thought that this side of Venus has a surface cracked by heat, and swept unceasingly by wind and dust storms of appalling velocity.

Schiaparelli, whose observations led to the adoption of the view that the aspect of Mercury remains fixed, was the pioneer in the case of Venus also. Finding certain definite markings on the planet, he watched them intently day by day, and found that their position remained constant, or so nearly constant that the period of the rotation of Venus could hardly be shorter than the period of its revolution round the sun. Similar observations, made by Lowell and his assistants in Arizona, not only confirmed Schiaparelli's conclusions, but threw new light on the markings of Venus. The planet was examined under better conditions of observation than ever before, with the result that the details of its surface came out with unprecedented clearness. Instead of isolated points, distinguished by their greater brightness or darkness from the surrounding surface, Venus now showed a very remarkable system of faint but perfectly definite and constant straight streaks, or lines, across its face, in a notably geometrical arrangement. By observation of these, it was soon possible to affirm that the period of the planet's rotation on its own axis coincides with the period of its revolution round the sun. The constancy of the markings showed, further, that they are not forms of cloud, and their clearness revealed that Venus is not, as had been thought, wrapped in a cloud-mantle.

The most characteristic markings are radial streaks which run inwards from the circumference of the planet's disc toward its center; they are broad and definite at the circumference, but become fainter, narrower and less clearly defined as they converge. Lowell believed these streaks to be marks of wind currents in the atmosphere. He explains them thus:

"One face baked for countless æons, and still baking, backed by one chilled by everlasting night, while both are still surrounded by air, must produce indraughts from the cold to the hot side of tremendous power. A funnel-like rise must take place in the center of the illuminated hemisphere, and the partial vacuum thus formed would be filled by air drawn from its periphery, which, in its turn, would draw from the regions of the night side. Such winds would sweep the surface as they entered, becoming more superficial as they advanced, and the marks of their inrush might well be discernible even at the distance we are off. Deltas of such inroad would thus seam the bounding circle of light and shade."

The theory is ingenious, but it would be more convincing if there were not other linear markings, not differing in appearance, which do not follow the radial direction. These tremendous wind currents, however, must continually sweep the surface of Venus; and it is difficult to resist the further conclusion, suggested by Lowell, that their effect will be to take up all the moisture on the sunward side of the planet and deposit it in the form of snow and ice upon the dark side. Or, rather, that must have been their effect in the past, for the process was probably completed ages ago. Again, the incessant hurricanes, driving over the arid regions exposed to the sun's heat, are presumably laden with dust, which may partly explain the dark shading of the radial markings, and partly explain also the intense efficiency of the planet's atmosphere as a reflector of light.

Like the planet Mercury, though much more rarely, Venus crosses the face of the sun. As we have seen, it completes its annual revolution in 224.7 days, but the earth is revolving round the sun, though more slowly, in the same direction; so that Venus is in inferior conjunction — that is to say, comes between the earth and the sun only once in every 584 days. Transits of Venus would therefore occur once in about every nineteen months, if Venus were always in the plane of the ecliptic. But the plane of its orbit is inclined by more than three degrees to the ecliptic, so that when the planet comes into inferior conjunction it is generally either above or below the ecliptic. Four times, however, in every 243 years Venus is at the same time on the plane of the ecliptic and in inferior conjunction with the sun, and there is a transit.

These transits always take place in June or in December but at irregular intervals, namely, 121½ years, 8 years, 105½ years, 8 years; after which the cycle is again repeated, and so on. It will be noticed that the first period is equal to the sum of the other three. A transit of Venus is plainly a rare event; the last took place on December 6, 1882, and the next will be on June 8, 2004.

The rare transits of Venus an astronomical event of great importance

The transit of Venus must always remain an astronomical event of great interest, though it has not now the same unique importance it used to have, because more exact means have been devised for determining the distance of the sun from the earth. Thus, the effects of the sun's gravitation upon the moon, and again the time which light takes to travel from the sun to the earth, are now used for the calculation of the sun's distance from us. Before these methods were thought out, however, astronomers were dependent principally upon the transit of Venus for this very important measurement.

How astronomers calculate the distance of the sun from the earth

The method used in these observations may be briefly explained as follows.

Let us imagine that two observers, one of whom is situated as far north as possible on the earth's surface, and the other is situated as far south as possible, are watching the same transit of Venus. It is obvious that the northern astronomer will see Venus sail across the sun's disc along a lower line, and the southern astronomer will see it cross higher up the disc; and, of course, these two lines will be parallel to one another, and near together, on the sun's disc. One of these lines will be longer than the other, because it will cross the disc at a wider part. Viewed from one of the stations on the earth, the transit of Venus will occupy a longer time than it will occupy when viewed from the other station. From the difference of the periods which the transit has taken at the two stations, together with a knowledge of the distance between the two stations, it is possible for mathematicians to calculate the distance of the sun from the earth.

In order to observe the transits of Venus in 1874 and again in 1882, astronomical expeditions were sent out by all the more advanced nations to every part of the world from which these transits could be seen, but with only partial success.

THE RETURN OF THE WATERS

Sources, Tracks, Windings, Vagaries,
Volume, Color, and Taste of Rivers

DISTRIBUTION OF THE CHIEF RIVERS

RIVERS may be defined as streams of fresh water of considerable size which run downhill, and ultimately flow either into the sea or into an inland lake. The water is, directly or indirectly, rain or melted snow. Again, it is vapor from the sea that makes the rain and snow. And so we have a constant circulation of water — sea, rain, river, sea, rain, river — "into the place from whence the rivers come, thither they return again".

Looking at the matter in another aspect, we may say that a river is a result of evaporation, condensation and gravity. The water vapor evaporated from the sea is condensed into rain, and the rain, falling upon the irregular land, is gathered together into certain channels by gravity, and led downwards to the sea again. Here we see one of the many missions of the mountains. The cold, rough hands of the mountains it is that clutch the clouds and condense the rain; the mountains it is that give gravity its opportunity and determine the direction of the water's flow. Wherever there are mountain ranges we have cold condensing surfaces; and where the peaks are snowy or icy their efficacy as condensers is naturally increased. Well known are the cloudcaps that so many mountains wear, and the cloud-banners that stream away from snowy or icy peaks when a wet wind blows.

With his customary eloquence, Ruskin describes the relationship of mountain and river: "Every fountain and river, from the inch-deep streamlet that crosses the village lane in trembling clearness, to the massy and silent march of the everlasting multitude of waters in Amazon or Ganges, owe their play and purity and power to the ordained elevation of the earth. Gentle or steep, extended or abrupt, some determined slope of the earth's surface is of course necessary before any wave can so much as overtake one sedge in its pilgrimage; and how seldom do we enough consider, as we walk beside the margins of our pleasant brooks, how beautiful and wonderful is the ordinance — of which every blade of grass that waves in their clear waters is a perpetual sign — that the dew and rain fallen on the face of the earth shall find no resting-place; shall find, on the contrary, fixed channels traced for them from the ravines of the central crests down which they roar in sudden ranks of foam to the dark hollows beneath the banks of lowland pasture, round which they must circle slowly among the stems and beneath the leaves of the lilies; paths prepared for them by which, at some appointed rate of journey, they must evermore descend, sometimes slow, and sometimes swift, but never pausing; the daily portion of the earth they have to glide over marked for them at each successive sunrise; the place which has known them knowing them no more; and the gateways of guarding mountains opened for them in cleft and chasm, none letting them in their pilgrimage, and from afar off the great heart of the sea calling them to itself: 'Deep calleth unto deep'!"

But the mountains do more than gather and condense rain to make rivers; they also store it. When man wishes to store water he builds huge tanks and reservoirs, but when nature wishes to store water

she collects it in spongy mountain marshes and boglands, or she freezes it into snow and ice. Snow and ice especially are nature's contrivance to build up a reserve of water against summer drought. All winter, when the rainfall is heavy, she piles up enough snow and ice to make cataracts in the spring, and to irrigate the lowlands in the summer. The same sun she used to lift the water she uses to thaw it. In the summer many rivers would be dried up just when most needed were it not for this cold storage.

SUNSHINE ABOVE AND RAIN BELOW — A CLOUD THAT CONDENSES ON MEETING A MOUNTAIN

In every country and continent it will be found that there are elevated lines and mountain ranges which produce slopes in opposite directions, and thus direct the course of running water either one way or another, more or less after the manner of the ridge and pitch-roof of a house. These directive elevations are known as watersheds, or divides. A watershed, or divide, is indeed the intersecting line of two divergent slopes causing diverging rivers; though the term watershed is also used to designate the entire slope.

THE ALLALINHORN, SWITZERLAND, WITH AVALANCHE DÉBRIS ON THE FEE GLACIER IN THE FOREGROUND

The location of a divide often has momentous consequences. The watershed, for instance, known as the Continental Divide, running through Montana, Wyoming, Colorado and New Mexico, decides whether rain shall flow into the Pacific or into the Atlantic and the Gulf of Mexico. Two streams of water, rising a few feet or inches apart on a plateau in the interior of Brazil, may reach the Atlantic thousands of miles apart. A few inches eastwards or westwards, northwards or southwards, make a world of difference. Again, the divide between the basins of the Mississippi and the St. Lawrence decides destinies as different as the courses of these two rivers; and in this case the divide is so low that in times of flood it is possible to pass by canoe from one river to the other.

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THE LOWER SOURCE OF THE RIVER JORDAN

This spring at Tell-el-Kadi, or Dan, bursts forth into a wide crystal pool, sending forth at once a broad river into the plain.

We have said that most rivers are originated by rain which trickles and runs into certain channels, but in many instances they originate only indirectly in this way; often their source is a spring. In other cases, they gush out from underground almost fully formed. This is the case with a river that flows into Klamath Lake, in the south of Oregon.

The area of country drained by a river is known as its "basin", and this area is, of course, delimited and defined by watersheds. The actual course of a river is known as its "track", and in a typical river it may be divided into three parts — the mountain or torrential track, the valley track and the plain track.

The torrential or mountain track has a slope of fifty feet or more in the mile. Down such steep tracks rivers rush headlong, often at a rate exceeding twenty miles an hour. The torrent of water pouring over a rough bed works much destruction, uprooting trees, rolling down boulders, eroding away rocky or earthy banks, cutting deep ravines in the mountain-side.

The valley track has a slope of up to ten feet per mile, giving a velocity to the stream of up to five miles an hour. A moderate current runs at the rate of one and a quarter miles in the hour. In the valley track of its course a river both constructs and destroys; it carries débris from place to place.

Rushing along at eight miles an hour, a stream can displace boulders four feet in diameter; "at two miles an hour stones as large as a hen's egg are rattled along; at one and a third miles an hour the current can just roll pebbles one inch in diameter; when gliding at half a mile an hour, gravel as large as peas is swept forward, while at a quarter of a mile an hour a river cannot disturb fine sand". The carrying power of a running water increases as the sixth power of its velocity so that if the velocity of a river doubles, its transporting power is increased sixty-four times; and if the velocity trebles, its transporting power is increased seven hundred and

twenty-nine times. In certain parts of its valley track a river will dislodge stones and gravel, and at other parts, depending on its velocity, will deposit them.

The plain track is the track of the river across level plains which often are formed of its own deposits. In this track its flow is often split, and hemmed, and dammed.

The courses of the Rhine, the Rhône, the Danube, the Ganges, the Indus, the Mississippi, the Amazon, the Nile and the Niger all can be divided into the above-mentioned tracks. When the slope of a river exceeds ten inches in a mile, or 1 in 6336, it is not navigable without locks. The rate of flow of a river is naturally retarded by irregularities of its bed; and the layers of water next the bottom and the banks, being retarded by friction, move less rapidly than layers of water towards the center. When a river is impeded by any obstruction along one bank, it forms a deposit at that point, and swerves round to the opposite bank, which it tends to scoop out. The scooped-out concavity, in turn, makes the water curve again to the opposite bank, where it repeats the scooping-out process. One curve necessarily leads to another like it, in conformity with the law of the reciprocity of curves. In the middle of its course the Mississippi forms a series of curves so much alike in shape and size that the Indians and earliest colonists used them for the purpose of estimating distances. The larger the stream, the longer the curve it describes. A brook may make several curves in a single small field, whereas a large river may make a curve of ten or twenty miles, and come back almost to the spot from which it started. These curves are called meanders, the name being

Photo Ewing Galloway, N. Y.

A STREAM STARTING FROM THE END OF A GLACIER ON MT. RAINIER

The elephantine mass in the background is the ice of the glacier, and the dirt and stones with which it is covered are dropped at the end of its slow progress as a solid mass to where it melts away in the rushing stream that issues from beneath it.

derived from that of the River Maiandros, in Asia Minor, along which many such curves are found.

Having made a loop, a river not infrequently takes a short cut again across the loop, and thus are produced diverging and converging arms with an island between. Sometimes, having made the short cut, it abandons the loops, which then become a crescentic lake of stagnant water known as an ox-bow lake. In the basins of the Mississippi, the Amazon, the Ganges, the Rhône and the Po there are many of these lakes. Those of the Mississippi are particularly abundant, and are tenanted by alligators, wildfowl and garfish. More than once by such a cut-off the Mississippi has shortened its course by about thirty miles, and has left riverside towns miles from its currents. Thus in 1876 the river cut across a tongue of land opposite the city of Vicksburg, leaving the northern front of the city on Lake Continental, the ox-bow lake thus formed. It was necessary to turn the Yazoo River through a canal across the upper end of the old channel in order to give the city a river front again. By changing its course it has even altered the boundaries of states. A man might go to sleep in his bed in the state of Mississippi, and waken next morning to find himself in Louisiana. Nor is it in America alone that the rivers play such geographical pranks. The Tweed has more than once, by altering its course, transferred farms from Northumberland, England, into Scotland!

A river famous for its vagaries is the Po, which, in some parts of its course, "only takes about thirty years in forming and destroying each of its meanders".

The Hoang-ho or Yellow River, in China, has often changed its course, and sometimes with such disastrous results that it has been named "China's Sorrow". In 1887 this river broke through its embankment, and submerged hundreds of villages, drowning over a million human beings.

The result of the winding or meandering of rivers is greatly to extend their course from source to sea. The Scottish Devon meanders for twenty-six miles, to cover a distance which is only six and a half miles as the crow flies. The Forth covers twenty miles flowing between Stirling and Alloa, though the distance direct is only seven miles. The Nile, by means of its meanderings, extends its journey by five hundred miles; and the Mississippi, between the mouth of the Ohio and the Gulf of Mexico, goes more than twice the distance, measured as the crow flies. These meanders reduce the gradients of rivers and render them more navigable, and they also increase the efficiency of rivers as means of drainage and irrigation.

Many rivers, as is well known, undergo great alterations in the volume of their water. For example, the Susquehanna

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THE MEANDERINGS OF THE RACQUETTE RIVER AS IT APPROACHES THE LAKE

River at Harrisburg has a mean discharge of about 39,000 cubic feet per second, as indicated by daily observations during a period of fourteen years, 1891 to 1904; but during this period the discharge was at times as low as 2400 cubic feet per second, and once reached a maximum of 544,000 cubic feet; a discharge of 200,000 cubic feet per second is of fairly frequent occurrence.

Heavy rainfalls and melting snow necessarily augment the volume of any river they reach, but the augmentation is not nearly so great as at first sight one would expect it to be, since by no means all the rainfall or snowfall goes to increase the bulk of a river. Much sinks into the soil and never reaches the river; much is evaporated; much is given away by the river to any thirsty land it waters. Thus the river discharge for the upper Mississippi reservoirs is about one-seventh of the total rainfall, while the average run-off of water for the whole Mississippi drainage-valley is about one-fourth of the rainfall, and throughout the United States the rivers carry off less than one-third of the precipitation, two-thirds being removed by evaporation. The Thames discharges less than a third, the Elbe about a quarter and the Seine not more than a third of the rainfall of their respective basins.

But though the volume of rivers is not always augmented in proportion to the rainfall and snowfall of their basins, yet the volumes of all rivers fluctuate to some degree according to their supply of water. Often these fluctuations are very sudden and very great. A mountain stream which may be only a runlet will, on the occasion of the first thaw, be suddenly changed into a river running thirty miles an hour, and big enough to overspread fields and wash away houses. There are, for instance, three little streams in France, the Doux, the Erieux, the Ardèche, which usually discharge 20 to 25 cubic yards of water a second, but during a flood in 1857 they discharged at the rate of 18,000 cubic yards a second — as much as the discharge under ordinary circumstances of the Euphrates and the Ganges. On this occasion the Ardèche rose to a height of 60 feet above

A RIVER ISSUING FROM THE MELTING SNOW IN AN ALPINE VALLEY

low-water mark. The Rhine is frequently flooded, and sometimes rises 23 feet, and discharges about 20,000 cubic yards of water a second. If all its mountain tributaries were in flood at once it would become a second Amazon, and would discharge more than 130,000 cubic yards of water a second. The Seine has been known to rise 20 feet, the Saône 24½ feet and the Danube 60 feet above low-water level; the difference of level of the Susquehanna in the two extreme cases mentioned above was 25 feet 8 inches.

river, and is lulled to sleep by the noise of the cataracts roaring over the rocks, but when he wakens at dawn next day all he sees is a slender rivulet of water, only visible here and there among the masses of gravel."

The fluctuations in volume of the Amazon are peculiar. This great river receives tributaries both from the northern and the southern hemisphere. The northern tributaries are in flood in summer and autumn, and the southern tributaries in winter, and so the level of the water

A RIVER VALLEY BELOW THE MOUNTAINS — THE BOW RIVER, ALBERTA

In tropical regions the rivers of medium size are usually dry half the year and in flood half the year. All round the Red Sea there is a perfect system of river-beds, but except during the season of the rains there is no water. One of these dried-up rivers, the Roumah, is 750 miles in length.

In some tropical valleys there are daily fluctuations owing to daily storms. "In the evening all the gorges are filled with masses of raging water; and the traveler finds himself compelled to put a stop to his journey. He bivouacs on the edge of the

in the mighty stream is kept high and pretty constantly in flood. The overflowing of the Amazon is a deluge rather than an overflow, for in places it makes a lake large enough to cover the whole state of New York.

"The great river was terrible to look upon," writes Herndon, the American traveler, "as it rolled through the solitudes with a solemn and majestic air. Its waters seemed to wear a wrathful, malevolent, and pitiless aspect. The entire landscape had the effect of stirring up in

the mind a feeling of horror and dread similar to that produced by the imposing solemnities of a funeral at sea, by the minute-gun firing at intervals, the howling of the tempest and the wild uproar of the waves, when the crew assemble on the deck to bury their dead in the bosom of a troubled sea."

In former days the Mississippi was subject to floods resulting in great overflows, but much has been done in recent time to confine the river between artificial embankments known as levees. The Ganges, too, has its flood, and every April converts the plain through which it flows into a lake 32 feet deep.

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THE DEVASTATING FLOODS IN THE VALLEY OF THE MISSISSIPPI

The most celebrated floods in the world are probably the periodic floods of the Nile, which irrigate and fertilize the land of Egypt. All of a sudden in dry, sunny weather the Nile rises, and continues to rise till at its highest its volume is increased ten or twenty fold. To the ancients the rise was a prodigy and a marvel, but we now know that the rise is due to rains and thawing snows on the Abyssinian mountains of the upper reaches of the Nile.

As is well known, rivers vary in color, and sometimes by their color they have been named. Thus, the Greeks have a river Aspropotamo, or White River, and there are many Rio Blancos, while a certain stretch of the Nile is known as the White Nile. There is also in the United States the Red River, and in China the Hoang-ho or Yellow River; while in Scotland there is the Blackadder, and in Masailand the Black River. It may be noted here, however, that the word "Orange" in "Orange River" refers to the House of Orange and not to the color of the river, and that the Niger is not so called because black, but because "N-eg-hirren" is the native word for "river".

In some cases the color of a river is due to the color of its bed or of its reflected banks. Thus, the Black River of Masailand appears black because of the black lava over which it flows. In other cases it is the contents of the river, such as clay or peat, that give the river its characteristic color. Thus, the Blackadder is blackened by its peaty contents; and there is an inky-black stream in Algeria whose waters are really black owing to the fact that one of its two tributaries absorbs iron from the soil, while the other absorbs gallic acid, the mixture of the two accordingly producing actual ink. Rivers vary also in taste according to the mineral ingredients they contain. Some are actually salt, like the Salt River of Australia, and some are acid, like the Rio de Vinagre, in Central America.

When we look in a general way at the distribution of rivers one of the first things that strikes us is the fact that the distribution is decidedly unequal, and that the Atlantic Ocean receives more than its fair share of river water.

How the Atlantic Ocean receives more than its share of river water

Into the Atlantic flow almost all the great rivers of the world — the Amazon, Mississippi, Orinoco, St. Lawrence, Paraguay, Paraná, Congo, Niger, Gambia, Danube and Nile. Into the Pacific flow only five big rivers — the Hoang-ho, Mekhong, Yangtse-kiang, Amur and Columbia.

Looking at the continental distribution of rivers, we find that Asia has three great rivers running northward across the great plain of Siberia, and four pairs of great rivers running southward. The three great Siberian rivers are the Ob, the Lena and the Yenisei. The four pairs of great southward rivers are the Tigris and Euphrates, flowing into the Persian Gulf; the Ganges and Brahmaputra, into the Bay of Bengal; the Indus and Sutlej, into the Arabian Sea; and the Hoang-ho and Yangtse-kiang, into the Pacific.

The great river systems of Europe, Asia, Africa and Australia

Europe has two great river systems — one that includes the Volga, Dwina, Niemen, Bug and Dnieper, which rise in marshy ground in the center of Russia; and one embracing the Rhine, Rhône, Danube and Ticino, which take their rise in the heart of the highest mountains. It is noticeable that the four last-mentioned each reach a different sea: the Rhine the North Sea; the Rhône, the Mediterranean; the Danube, the Black Sea; the Ticino, the Adriatic.

Africa has several great rivers — the Nile, Niger, Congo, Zambesi, Orange and Limpopo. All these arise in the center of the continent, but at great distances from each other, and all run comparatively straight courses and have few tributaries. The Nile flows into the Mediterranean, the Niger and Congo into the Atlantic, and the Zambesi, Limpopo and Orange into the Indian Ocean.

In Australia the only considerable rivers are the Murray, and its tributary, the Darling. Most of the others are in flood in the rainy season, and almost entirely dry in the dry season.

The western hemisphere's gigantic river systems

In North America there are two river systems arising from mountain ranges, and a third intermediate river system rising from an elevated plain. From the Union Peak range, in Idaho, radiate the Missouri, Colorado and Rio Grande del Norte. Further north, from the Murchison range, rise the Fraser, Columbia, Saskatchewan the Athabasca and the Mackenzie; while between these two groups, from a plain situated to the west of Lake Superior, spring the Red River of the North, the Mississippi and the St. Lawrence.

Of all the continents South America displays the greatest rivers, for it owns the Amazon, the Paraná and the Orinoco, while some of the tributaries of the Amazon and Paraná are themselves huge rivers. The Amazon and the Orinoco rise in the Andes, the Paraná from a high plateau in the interior of Brazil; and all three communicate by tributaries, so that there is a continuous network of water from the north of the continent almost to the south. The Paraná joins the Paraguay to form the estuary known as the Rio de la Plata.

It is a remarkable fact that the basin of the Amazon is the gentlest landslope in the world; even at a distance of 1900 miles from the sea it attains an elevation of only 600 feet. Its average gradient, therefore, for that distance is less than four inches in the mile, a decline so slight as to emphasize greatly the dimensions of the river, for, notwithstanding this leisurely flow, the volume of water discharged is enormously larger than that of any other.

The following table, collated by H. R. Mill, draws some interesting comparisons.

River	Area of Basin. Square Miles	Rainfall of Basin. Cubic Miles	Average Annual Discharge. Cubic Miles	Length in Miles
Amazon .	2,230,000	2834	528	3060
Congo . .	1,540,000	1213	419	2900
Nile . . .	1,290,000	892	24	4000
Mississippi .	1,285,000	673	126	4200
La Plata .	995,000	905	189	2000

MENDELISM UP-TO-DATE

Why Should not Laws Constant in Relation to the Propagation of Plants Apply to Man?

LATEST RESULTS OF AMERICAN TESTS

IT is not easy to keep pace with the progress of genetics unless we are prepared to devote ourselves to nothing else. Very much has been done since Mendelism first began to attract the attention of men of science; and the new study has no better feature than that the successive results are trustworthy — for the good reason that they are the results of actual experimental observation. Heredity has never been studied in this way before, or similarly valuable results would have been obtained long ago.

The work done by Mendel himself has been entirely confirmed, and, what is more interesting, his theoretical interpretation of it has been confirmed also, and extended, by the "presence and absence hypothesis" of Professor Bateson, who explains dominant characters as due to the presence of something in the germ-cells, and recessive characters as due to the absence of something from them. The characters in question may be normal or abnormal, good or bad; and for every case it has to be ascertained whether it is due to the presence of something in the germ-cell, or the absence of something from it.

This simple interpretation of the dominance and recessiveness discovered by Mendel is the chief contribution to the theory of the subject since its rediscovery. Mendel rightly looked upon the gametes of his peas as bearers of something capable of giving rise to the characters of the plant, and he regarded any individual gamete as being able to carry one, and one only, of any alternative pair of characters — a given gamete could carry tallness or dwarfness, but not both. He regarded these two opposite characters as mutually exclusive so far as the gamete was concerned. It must be pure for one or other of these opposite characters, and this idea of the purity of the gametes is the most essential part of his theory. The "presence or absence" theory makes it intelligible; for if dwarfness be due to the absence of something which, if present, produces tallness, obviously every gamete will be pure in this respect; either the tallness factor will be present or it will not.

We have already seen that a tall plant, as in Mendel's experiments, may be of two distinct kinds. It may have nothing but tallness to transmit, but it may also have dwarfness to transmit, though that does not appear in itself, being overshadowed by the dominant tallness. In other words, the tall plant may be what we call a pure dominant, which will yield nothing but talls indefinitely; or it may be what is called an impure dominant, in which case half its gametes, on the average, will convey tallness, and half will convey dwarfness. No inspection of the individual plant will tell us to which of these classes it belongs, but that may be just the information we want. If, for instance, we want to breed a race in which the dominant character will be fixed, we must start with pure dominants, which have no dwarfness in them, for the purpose, and somehow we must distinguish them. But this can now be readily done, if we do not know the plant's ancestry, by the test of experimental breeding. We must cross such a plant with a pure recessive, whose gametes contain nothing but dwarfness. If the offspring are all tall, then it is evident that the tall parent is a pure dominant, producing nothing but gametes which carry the tallness, so that all

the offspring are tall, though from their other parent they get dwarfness. But if the tall parent be only an impure dominant, half its gametes will have the tall dominant character, and half will not. These mate with gametes none of which have the tallness in them, and the result is that the offspring of such a mating will be, on the average, half tall and half dwarf. Thus our experimental test, of crossing it with the recessive, has enabled us to say whether the plant showing the dominant character is a pure dominant, or an impure dominant bearing the recessive character. In the first case, all the offspring have the dominant character, and in the second they are half dominants and half recessives.

Illustrations of the Mendelian method of calculating ratios of breeding

We note also that these assertions hold good independently for any number of alternative characters in the same plant. For instance, in the pea, color of the flowers may be dominant to their whiteness, as tallness is to dwarfness. The Mendelian law is followed in all crossings, so that we get a number of possible forms, and these occur, on the average, in ratios which can be readily calculated. Thus, as Mendel showed, if, for example, the parents differ in three pairs of character, A, B and C respectively dominant to a, b and c, the crosses will, of course, all be of the form A B C, but the next generation will consist of 27 A B C, 9 A B c, 9 A b C, 9 a B C, 3 A b c, 3 a B c, 3 a b C and 1 a b c. The figures and symbols may be tiresome, but it will be seen at once what possibilities for the creation or "origin" of new forms, which may quite well be ranked as new species, are raised here.

Thus in the third generation, or the second filial generation in the modern terminology, we have six types of individual which did not exist before; and it may be possible, by appropriate means, to obtain individuals of these various types which will breed true. If we are dealing with wheat, for instance, instead of peas, such experiments may achieve more for agriculture than all the politicians that ever were or will be.

Some terms added to the familiar vocabulary of students of life

Two other recent terms, which we owe to Professor Bateson, must here be introduced, for they are very convenient, and will have to be part of the familiar vocabulary of students of life for the future. We have seen that a given individual, being formed by the yoking of two constituents, and being thus of double constitution, may be called a *zygote*, which means yoked. Now, any zygote may be of two kinds in respect to any Mendelian character. If that character (whether dominant or recessive) was borne by both of the gametes which were yoked to form the zygote, then, in respect to that character, the individual may be called *homozygous*, a fact which has the immensely important consequence that all the gametes borne by such an individual will bear the character in respect to which it is homozygous. The "pure dominants" to which we have already referred are thus to be styled homozygous; they are of similar origin from both sides, in respect to the character under discussion, and they will bear gametes of only one type in respect to that character.

On the other hand, a zygote may be formed by two gametes one of which bears the given character while the other does not. It is then said to be not homozygous but *heterozygous* in respect to that character. It will usually look and be, so far as itself is concerned, just the same as its homozygous neighbor, but it bears different gametes, for half of them will carry the given character and half will not. And here, again, the various pairs of characters are independent, so that any individual may be homozygous in respect to any character or characters, and at the same time heterozygous as regards others.

Where Bateson's studies have simplified Mendel's original views

We have just used the expression "pairs of characters", and now let us look more closely at what is apt to puzzle us. Why should characters be arranged like this in pairs? Mendel's own explanation of his discovery was that "in the gamete there

was either a definite something corresponding to the dominant character or a definite something corresponding to the recessive character, and that these somethings, whatever they were, could not co-exist in any single gamete". These somethings are the Mendelian factors, as we now call them, each of which corresponds to a unit-character in the developed zygote. It does not appear evident, however, why characters should exist in alternative pairs like this, and why there should be this impossibility of the simultaneous presence of, say, the factor for tallness and the factor for shortness in a single gamete. Professor Bateson's experiments and arguments have beautifully simplified Mendel's original views, and have made the facts reasonable. They are *not* opposite factors, as Mendel supposed, which produce opposite characters, and which, for unknown reasons, can never go together into a single gamete. On the contrary, all contemporary students accept the "presence and absence" theory of Bateson.

A simple statement of the modern theory by Professor R. C. Punnett

"On this theory the dominant character of an alternative pair owes its dominance to the presence of a factor which is absent in the recessive. The tall pea is tall owing to the presence in it of the factor for tallness, but in the absence of this factor the pea remains a dwarf. All peas are dwarf, but the tall is a dwarf plus a factor which turns it into a tall. Instead of the characters of an alternative pair being due to two separate factors, we now regard them as the expression of the only two possible states of a single factor, namely, its presence or its absence." Here, then, is the explanation of the fact that in all cases of Mendelian inheritance we can express our unit-characters in terms of alternative pairs, and we are able to formulate a definite conception of the living body in such terms as these, lately laid down by Professor Punnett: "A plant or animal is a living entity whose properties may in large measure be expressed in terms of unit-characters, and it is the possession of a greater or lesser number of such unit-characters that renders it possible for us to draw sharp distinctions between one individual and another. These unit-characters are represented by definite factors in the gamete, which in the process of heredity behave as indivisible entities, and are distributed according to a definite scheme. The factor for this or that unit-character is either present in the gamete or it is not present. It must be there in its entirety or completely absent."

The interaction of many factors in producing varied characteristics

This is a very definite and simple start, but most interesting complications soon arise. The factors, as we now assert, are independent in the gamete, each is distributed in subsequent generations according to its law as if the others did not exist. When we are dealing, as Mendel did, with factors that affect entirely different parts of the plant, that is all clear enough. But when we come to study separate factors which nevertheless affect the same part of the plant we soon see that, so far as the zygote is concerned, factors often interact and produce strange and unexpected results in the zygote or individual body from their interaction, though they each go their own strict way in the gametes from generation to generation. Thus, for instance, it is possible to cross certain white sweet-peas, and produce nothing but colored — say, red — offspring. It is like a chemical experiment in which two colorless fluids are mixed and a brilliant red precipitate results. And, indeed, the analogy to a chemical experiment may be more than an analogy. It may be — nay, must be — just such an experiment that we have performed in this case. The red color in the sweet-pea results from the interaction of two factors, like the mixing of the two colorless solutions in our chemistry. Unless both of these factors are present, the red color cannot appear. Now, in each of the white parents one of these factors was present. The cross between them brought the two complementary factors together; they produced their mutual interaction, like the solutions in a test-tube and so all the resulting flowers were red.

An illustration of genetic interactions from chemical science

Naturally, this red precipitate, so to call it, which has been deposited in the petals by this process, becomes of rare chemical interest. Can the chemists extract it for us, and find, perhaps, that it is a salt made of an acid and a base, like some red salt of iron that can be made in the chemical laboratory? In this case, as probably in others of the kind, it seems clear that a chemical process of a rather different kind is at work, but yet one which depends upon the interaction of two distinct substances. Probably there is a colorless substance, or rather a white substance, which has certain potentialities, so that it may be called a "chromogen", or color-begetter. This substance can scarcely itself exist in a gamete, but the conditions which produce it in the developed flower must do so, and one of the white parents makes this contribution, apparently. Now, what this chromogen requires in order to form a red pigment is some agent which will partially oxidize it — in a word, an oxidizing ferment. Probably, then, the second white parent contributes this ferment, or rather a factor which leads to the formation of this ferment, in the gamete which it provides. When the chromogen from the one gamete and the ferment from the other meet, the chromogen is oxidized and the red pigment is produced.

This is not to be taken as quite proved, so far, and we have somewhat simplified the facts for the purposes of the argument; but it will now be clear what is meant by interaction of factors, and why we are entitled to say that the production of red from the mixture of two whites has more than an analogy to the feats of the chemist with his test-tubes.

Ultra-microscopic complexities of constitution revealed by Mendelian study

But this is merely the beginning, though an immensely important one. It teaches us that apparently simple things may be due to the interaction of distinct factors. If this be true for redness in sweet-peas, how much more is it not likely to be true of, say, genius in man? It is not too much to say that no thoughtful person can seriously look at these recent Mendelian discoveries without once and for all forming new notions as to the complexity of the constitution of living things, and, above all, of the highest and most complicated species we know. Observe, further, that here experimental breeding reveals complexities of constitution and composition which no knife or scalpel and no microscope could ever reveal. This is something subtler and more minute and more profound than microscopic anatomy, or even physiological chemistry. The anatomist may trace the pigment to certain parts of the petal, and the chemist may extract and analyze it. But only the Mendelian can peer so much deeper than either as to tell them that this pigment is essentially a double thing due to an ingredient derived from one parent, and a second ingredient derived from the other.

A theory that equally explains new characters and reversion to an ancient type

The interaction need by no means be confined to two factors. Thus colored stocks may either have the leaves and stem covered with tiny hairs, or those hairs may be absent. No method of investigation but one can tell us anything more about these tiny hairs than that they are there, and have the ordinary structure of such hairs. But experimental breeding has proved that the presence of even such a simple and unimportant character as this is due to the necessary interaction of three factors. Unless all three meet in the zygote the hairs cannot appear, but those three factors are separately distributed in the descendants, according to the ordinary Mendelian law. Imagine the hopelessness of trying to study the inheritance of this hairiness by the old methods, finding it come out of nowhere, and go nowhere; and the contrast with the Mendelian method, which reveals the order of inheritance and the constitution of the individual at one and the same time!

We are not to suppose that the interaction of factors is necessarily of the types described above, though they illustrate it so well. Sometimes, as we have seen, a

new character appears from the conjunction of two factors; or this "new" character may be of immense antiquity, as in those cases of reversion where the appearance of the ancestral form in the crosses is due to the coming together of two factors which have long been separated in the course of evolution. But the new character, or the reversionary character in some cases, may no less be due to the absence of two factors in the zygote, the absence of one having been "contributed", so to speak, by each gamete concerned. Only in the zygote in which just these two factors are absent can the new or old character appear.

The inhibitory or arresting action of one factor on another

Yet again, factors may interact in other ways. The zygote may inherit from one gamete a factor which would naturally produce such and such a characteristic. But from the other gamete which goes to its constitution it may inherit a factor which inhibits or arrests the action of the first, and so the character in question cannot appear. For instance, wheats may be bearded or beardless. The presence of the beard is here palpably something additional to the structure; and we might reasonably expect, on the "presence and absence" theory, that the bearded condition will be dominant, due to the presence of the factor for the beard, and the beardless condition will be recessive. The reverse is the case, however. The beardless condition is dominant, and the explanation is that it is due to the presence of a factor which prevents the beard from growing. An obvious illustration of the difference is the case of the beardless boy, and of the beardless man who is beardless because of a positive factor the presence of which prevents the appearance of his beard — namely, his razor. In short, the same visible effect may be produced, in many instances, either by the omission of a factor, or by the addition of a factor which has the preventive or suppressive action. Thus dominant and recessive white poultry are indistinguishable in appearance, but the former contain a factor more, and the latter a factor less, than the colored bird. The foregoing, especially in those cases where the interaction of factors, meeting again after ages of separation, produces a reversion to the wild or ancestral form of the species, obviously bears upon one of the great evolutionary questions — the relation of wild forms to domestic varieties.

Why new characters sometimes appear suddenly and complete

The classical idea is that the domestic forms have been produced by the long and patient continuance of selection; and, as we remember, Darwin argued from this artificial selection, carried out by man, to what he called "natural selection", carried out by nature, and similarly originating new species there. But, in point of fact, as for instance in the sweet pea, the new character does not arise from a pre-existing variety by any process of gradual selection. It turns up suddenly, complete in itself.

Something has happened in the gametes; and our experiments show us what this something has been in many cases. If the bringing together of factors often yields us a reversion to the wild form, it must be that the domestic variety was formed by the dropping out of certain factors, and that is the simple relation between them. Some of the domestic varieties are due to the lack of one factor, some to the lack of another. Put them together, and we have offspring in which all the factors once associated again meet; and the phenomenon of reversion on crossing, about which so much astonishing nonsense used to be written, is at once explained. This seems to be clearly true of many species, including sweet-peas, rats and rabbits.

Cases of apparent attraction and repulsion between genetic factors

In other instances the action appears to have been of an opposite kind, and the more recent form is due to the interpolation or addition of a new factor which was not present in the ancestor. This appears to be the case as regards the color and some other characteristics of wild and domestic pigeons, and the same seems to be

true of the hornless or polled condition of cattle. Their wild ancestors were, no doubt, horned, and the hornless state has been shown to be dominant, like the beardless state of wheat. Here, then, a new factor has been added in the course of evolution, though its action is an inhibitory one, and though at first we should naturally suppose that the modern hornless cattle had lost a factor which produced the horns in their ancestors. The fact is that they have gained an inhibitory factor, like modern man with his razor.

We now come to a new and most important complication. We have already seen how factors may interact, but all the factors under discussion are transmitted independently. So far as transmission is concerned, each behaves, we have insisted, as if the others were non-existent, though their interaction produces such marked results upon the zygote or individual. But now we encounter cases where the factors do affect one another in their transmission — cases where they repel one another, so that they seem to decline to enter into the same gamete, and other cases where they seem to enter into the same gamete by preference. This problem may be summarized as that of the repulsion and coupling of factors; and a moment's thought will show what large consequences may be involved, above all for the case of man, if the factors for certain characters, desirable or undesirable, have a tendency to be habitually linked in heredity with factors for other qualities, or simply decline, so to speak, ever to be combined with certain other factors.

The suggestion by genetics that the sex of an individual is a Mendelian character

These phenomena clearly show that there may be natural limits to what even experimental breeding may do, no matter how definitely the laws of transmission are known. The reader is carefully to avoid confounding this new problem with the primary one — that opposites cannot go into the same germ-cell. That, we said, meant that opposites are due to the presence or absence of one thing, called a factor, and that the factor must plainly be either present or absent in any given case. But now we learn that sometimes factors which do not stand for opposites, and would appear to have no relation at all, repel each other, or are coupled with others, in the process of gamete formation, or gametogenesis.

The practical importance of this will be evident when we consider it in relation to the phenomena of sex. As has been already hinted, the modern developments of genetics demonstrate that the sex of an individual is one of its Mendelian characters, or is at any rate based thereon. And it may well be, as many instances suggest, that the factors for sex, male or female, are especially liable to repel, or to couple with themselves, other factors that have nothing whatever to do with sex as sex, but may yet have the result of giving certain characters to individuals of one sex as compared with the other.

No one can look at the familiar Mendelian ratios — as, for instance, the half and half which we see when we cross an impure dominant with a recessive — without remembering that, on the average, the offspring of male and female parents exhibit the same ratio as regards their sex. Might it not be, then, that one of the sexes is an impure dominant, being heterozygous in respect of a factor which the other does not possess — a factor which determines sex?

Cases in which maleness and femaleness are equally balanced

At any rate, in some instances it appears to be the case; the female possesses a femaleness factor which is absent in the male. But she is heterozygous in respect to this factor, not having received it in the gamete from the male parent. Hence, adopting the usual symbols and calling the dominant factor for femaleness F, and its absence f, we find that the constitution of the female is Ff, and of the male is ff. This being so, we should expect the numerical proportions of the offspring to be half male and half female, as in all other cases where an impure dominant is mated with a recessive. All the gametes from the male are without the femaleness factor; on an average half the gametes from the female

will have the femaleness factor, or F, and half will be without it, and so the offspring will be half composed of f × F, and half of f × f — half female and half male. This we here assert only for certain species; the case may be quite different with others.

The likelihood of a scientific foundation for sons resembling mothers

Various instances of coupling and repulsion between the factors for sex and the factors for other characters have been met; and Professor Punnett's conclusion as to the particular case of the brown Leghorn hen is too interesting not to be quoted: "The mother transmits to her daughters her dominant quality of femaleness, but, to balance this, as it were, she transmits to her sons another quality which her daughters do not receive. It is a matter of common experience among human families that in respect to particular qualities the sons tend to resemble their mothers more than the daughters do; and it is not improbable that such observations have a real foundation, for which the clue may be provided by the brown Leghorn hen."

The case of this hen shows that a certain factor cannot enter, by a double dose, one from each side, into a gamete which also contains femaleness. She can give her daughters a single dose of this particular factor, but that is not enough. At any rate, we know that in some cases the qualities of an individual are markedly different according as to whether he or she has received a single or a double dose of a given factor. Hence, as Professor Punnett argues: "It is not inconceivable that some of the qualities in which a man differs from a woman are founded upon a distinction of this nature. Certain qualities of intellect, for example, may depend upon the existence in the individual of a double dose of some factor which is repelled by femaleness. If this is so, and if woman is bent upon achieving the results which such qualities of intellect imply, it is not education or training that will help her. Her problem is to get the factor on which the quality depends into an ovum that carries also the factor for femaleness."

The wide application of the Mendelian law to man now certain

This may require qualification, but it is a suggestion too interesting to ignore. For undoubtedly modern genetics comprises man. The Mendelian law has been found to apply in so many species of animals and plants that the probability of its application to man has been increasing year by year. Genetics today can demonstrate its laws in such various cases as the height, hairiness, flower-color and flower-form, the shape of the pollen grains and the structure of the fruits in plants; the coat-color of many mammals, the form of the feathers and the comb in poultry, the waltzing habit of Japanese mice — and now man must be added.

A long-standing objection is to the effect that, in the United States, there are a large number of mulattoes — children of white people and negroes — whose skins are intermediate in color, and whose offspring are like them. In point of fact, this question has not yet been properly worked out, and should not be pronounced upon. But several families have been described, of unions between white people and Indians, where there is clear evidence of the segregation of the color, and its behavior in a fashion which will doubtless be reduced to the Mendelian law.

It has also been definitely shown that the inheritance of certain constituents of eye-color is Mendelian, brown being dominant to blue. This is at present the only normal human unit-character that has been definitely shown to obey the Mendelian law, but the existence of one such character speaks volumes for what future inquiry may be expected to reveal.

The Mendelian rules of heredity shown in transmission of human abnormalities

As for the human abnormalities which have lately been shown to be Mendelian in their transmission, their number increases month by month. There is, for instance, an unusual deformity of the fingers and toes, known as brachydactyly, or short-fingers, in which the fingers and toes have only two bony segments instead of three.

This is a defect in the number of anatomical elements, but it has been shown to be a Mendelian dominant, due to the presence of something which is not present in the normal gamete. The demonstration is of practical moment, for it means that unaffected individuals from the affected stock cannot transmit the defect. They are recessives, and their children will remain so, like all other normal people.

Several peculiarities of the skin and of the front parts of the eyes, including the lens, which are formed from the skin, have been shown to obey the Mendelian law in man — such as a peculiar tendency to blisters, a no less peculiar thickening of the skin in the palms and soles, and cataract (opacity of the lens) which comes on in early life, instead of in old age, and is hence known as pre-senile cataract.

The Mendelian law in relation to certain forms of blindness

Elsewhere in this work it has been shown that certain mental conditions are also Mendelian, the peculiarity in these cases behaving as a recessive, unlike the case of brachydactyly. Certain nervous disorders, affecting the spinal cord and its nerves, including one which was first identified by the famous English physician Sir William Gowers, and is named "Gowers' disease", after him, must also be included in this category. There is also the extraordinary record of a family in which many members are "night-blind" — *i.e.*, unable to see at all in moonlight or twilight, the retina being insensitive to light which is quite sufficient to excite it in normal people. The records here go back to early in the seventeenth century. More than two thousand descendants of a "night-blind" individual then born have been recorded. For ten generations and nearly three centuries this peculiarity has been transmitted as a Mendelian dominant.

Finally — for the present — there is the group of strange human cases in which the factor concerned in the peculiarity and the factors for sex are somehow coupled or repelled.

Thus it happens in color-blindness, almost invariably; in the disease known as hæmophilia, which is an abnormal tendency to bleed uncontrollably from slight causes; and in various conditions of the eyes and the nervous system, the general rule is that "males suffer and females transmit". In some of these cases a simple interpretation would be that the abnormal character is dominant in males and recessive in females. The women in such instances are free from the defect, and so are their daughters, but it appears in their sons. As to the children of the affected males, we have not yet sufficient evidence.

The immeasurable promise the science of genetics makes to the future

Such is the extreme limit to which this great new science of genetics has attained at the time when these words are written. The extent of its promise, within its appointed limits, is immeasurable. As we have seen, it is giving us an analysis of what appear to be simple and single characters of the individual body the real nature of which could have been ascertained in no other way. It is enabling us to construct new living forms, which breed true, and which may be very useful. But it essentially deals with characters or factors which are already presumed to exist. It re-shuffles them, but does not create them. Though entire novelties may appear, such as might be called new species, they are due only to a novel combination of factors already existing. But, plainly, there are deeper questions. The highest forms of life contain more factors than the lower. Where and how did those new factors come into existence? Here is room for experiment of an entirely distinct kind, on which some notable pioneers are now working in America; and to this experimental biology, as it is called, we must next direct our attention. But here we are without any such key as Mendel provided, and we may yet have to acknowledge that we are in the presence of the ultimate — the creative force of which all life is the manifestation.

HOW PLANTS ARE SPREAD

The Arrangements Whereby Stationary Growths Prevent Overcrowding by Despatching Their Seeds to a Distance

UNCONSCIOUS SERVANTS OF PLANTS

WE now come to the consideration of one of the most interesting aspects of the life of plants — namely, that of their distribution in the world, or, as it is termed, plant geography. The specialization of function for various definite purposes is nowhere better exemplified than in plants, and we have already studied some of the physiological processes which are carried out by means of special devices. The dispersal of plants over the surface of the earth is another of these definite objects which plant life has to manage in order to survive; and it is almost more necessary to plants than to animals that special means of attaining this end should be developed, for the simple reason that the majority of plants have a definite fixed position in which they grow. All of the higher animals are provided with organs of locomotion; and in their case specialization of these organs, when it occurs, is directed frequently to increasing the speed of their movement, as we find in the wings of birds, and in the limbs of an animal such as the deer.

But although we usually regard plants as living creatures in a fixed habitat, a moment's thought will show us that unless the plant is provided with some means which will permit of its *offspring*, at least, being transported to some distance, it could not possibly survive as a species; or, at least, it could never increase very much in number. It would be in the same position as a human community — restricted either by geographical or other limitations within a given area, beyond which, no matter how great the increase in the population, the individuals could not go.

The inevitable result would then be that, as soon as the individuals reached the number which was the greatest that could be carried by the area in which they lived, every single individual above that number would either be starved for lack of food or would otherwise perish in the struggle for existence. This actual process occurs in nations, which therefore require, as an urgent necessity, colonies or dependencies for their surplus population.

So it is with plants. A very few generations in plant life would bring about such a congestion and crowding in the immediate vicinity of the parent plants that no more could survive unless nature provided some means of dispersal for the younger generations. The necessity is so urgent that we no longer wonder, once we have recognized it, that the variety of means which have been evolved in plants to attain this end is almost infinite. To some of the more striking of these adaptative arrangements we may now turn our attention.

Among the cryptogams, those lowly plants whose organs of fructification are concealed, or not visible, a very common means of propagation is by means of spreading roots, which travel along underground considerable distances, and so extend their area of living. This is seen in the ferns. But most of these flowerless plants reproduce themselves by some sporing arrangement in which the actual spore itself is so minute an object that it is carried with the greatest of ease by even very slight movements in the air, and, of course, with still greater ease by moving water.

The distance to which such minute spores may be transported from their original home can hardly be estimated. Doubtless there is nothing to prevent the contents of the ripe puff-ball — full of fine, powdery spores — from traveling over a whole continent in the air, or even traversing a mighty ocean in a storm of wind; while as for the spores of the marine plants themselves, their limit of distribution is only to be gauged by that of the ocean currents themselves. All that is necessary is that the living principle in the spore be protected sufficiently in order to survive the long, hazardous journey.

CREEPING ROOT OF POLYPODIUM VULGARE

We have seen in an earlier chapter that certain plants propagate themselves, amongst other means, by runners or root-stalks, and this is another way in which the plant may gradually come to spread over quite a considerable area. Then, in a somewhat analogous way, we have the spreading of the roots under ground, and the sending up of shoots at intervals, as is seen in the case of trees like the silver-leaf poplar, which may do great damage on lawns by the number of shoots that spring up from underground roots coming from a distant tree. In a state of wild nature such trees as this silver-leaf poplar depend upon this method of securing a wide enough area to maintain the species.

THE UNDERGROUND ROOT-SPREAD OF GRASS ON A SAND DUNE

This also occurs in beeches, oaks and a number of other trees. The herbs show this habit also, as many who have fought quack-grass will realize.

A more unusual and very striking method of gaining the same end is for the branches of a tree itself to grow towards the earth, and on reaching it to strike root. This is, of course, only an exaggeration of the process of the runner, as seen in the strawberry. But it looks the more odd to see a large branch hanging freely from a considerable elevation, and then striking root. But branches may aid in distribution by dropping off the tree altogether, and being carried either by wind or water to some considerable distance, where, again, roots quickly appear from the broken end of the branch. Some of the willows and poplars exemplify this process extremely well. Among the herbs the walking fern offers probably the most interesting example of this phenomenon.

Then we have the large subject of the dispersal of seeds themselves by different mechanisms on the part of the plant, some of which we shall have to study almost immediately. But far more commonly than by a special mechanism are seeds spread by external agencies, particularly wind, water and animals, and artificial means of communication between places and countries wide apart.

LIFE THAT MAKES THE WIND ITS CHARIOT

WIND-BORNE-SEEDS OF THE DANDELION

FLOATING SEEDS OF THE CARBINE THISTLE

WIND-DISTRIBUTION OF THE SEEDS OF THE HAWKWEED

Occasionally the transport is materially aided by the living principle being inclosed within a hard fruit structure. Sometimes, however, it is the seed itself which is so modified as to help its own progress. But all these arrangements, no matter how diversified they may be, have the same object — namely, to avoid overcrowding of individuals in one district.

A RIPE BULRUSH AND ITS SHED SEEDS

Another very curious arrangement for this purpose is seen in such fruits as, when ripe and dry, burst open with a considerable degree of force, and throw the seeds some distance, as is the case with touch-me-not or jewel-weeds, geraniums, violets, oxalis and witch hazel. This process is in some plants attended by quite an audible noise.

Then we have fruits and seeds in considerable number that may be termed "winged", because of the remarkable membrane-like wing attached to them, which serves the purpose of sails, and by means of which dispersal is aided. Examples of this particularly interesting, though quite common, type of dispersal are seen in the ash, the elm, the maple and other trees, those of the maple being figured on page 2743. Still others have exquisite little tufts of fine hair which serve as parachutes, as is the case with the sycamore. When set free into the air the seeds are carried by currents of wind to immense distances by the hairs acting much as the sails of a ship.

This arrangement is one of the most perfectly successful of the means for dispersal, as may be gathered from the observations of the number of thistles and dandelions that spring up in any district where these plants are allowed to mature. Each of them produces tufted or parachute fruits in great numbers, as do many other plants, and consequently their distribution is world-wide. Another arrangement is that of certain plants which, when dried up, are easily blown about over the surface of the ground, and drop a few seeds here and there as they go. The more rounded in form such a plant is, and the lighter in structure, the better will it carry out its mission. Russian thistle, tumbling mustard and a species of panic grass illustrate this well.

MOSS SPORES CAST TO THE WINDS
From a highly magnified photograph.

An exquisitely ingenious arrangement is seen in the capsule of the common poppy, which is constructed practically on the same principle as a pepper-shaker. Within the capsule in the poppy an immense number of minute seeds are produced, and when the period of maturity arrives these are shed in small quantities at a time through

apertures that allow only a certain number of them to emerge at once. Very similar arrangements are to be seen in the monk's-hood and the larkspur.

It is difficult to estimate the importance of water in plant distribution, but anyone who will take the trouble to collect a number of the fruits and seeds of plants, and place them in a pan of water, will be surprised to observe how large a proportion will float. Still more interesting is it to leave them for a day or two, and notice what proportion will still remain on the surface of the water. In this way it is brought home to one that water-carrying must be a very important means of seed-dispersal. The current of river and stream, the breeze that ruffles the lake or ocean, supply the motive power for these seeds.

Then many plants have evolved arrangements by means of which any passerby, be he man or beast, is compelled, willingly or unwillingly, to assist in their distribution. Everyone is familiar with the burrs which adhere to one's clothes after a walk in the country at a certain time of the year. These outgrowths take the form of hooks of some sort or other; and so effective is their strength of attachment that it is hardly possible to get them out of the hair or wool of cattle and sheep without actually cutting the hair with them. A very interesting case is quoted by Joseph Young Bergen in this connection. A buffalo, whose hair was full of some fruits of a peculiar kind of grass, was sent as a present to a leading personage on the island of Ternate, in the Malay

GOOSE-GRASS BURR

THE BATHURST BURR

THE HOOKED AVENS SEED

One of the best known of these water-travelers is the cocoanut palm. It has been estimated in some cases that the seeds of this palm have found a new home by floating more than a thousand miles uninjured. An examination of the fruit shows how easily this might happen. Quite a large number of species of plants are known to disperse themselves by thus drifting in currents of water. Many of the sedges, docks and other plants growing near our freshwater streams and ponds may use a similar method to disseminate their seeds and fruits. The fruits of sedges are frequently contained in a little sack which floats, and those of dock have floating devices which remain attached to the fruits when they are shed.

Archipelago. This particular kind of grass, hitherto unknown there, rapidly spread over the whole island as the result of this method of introduction.

Then, of course, we have the whole army of stone-fruits and fleshy fruits to consider in this connection, because most of these being eaten, either by man himself or other animals with more or less similar tastes, are naturally very important means of scattering the seed within the fruit, the fleshy part being eaten and the seed discarded or in some cases the seed passing through the alimentary tract of the eater. It is worth noting, in passing, that possibly the deliciousness of these fleshy fruits has been evolved quite definitely for the special purpose of scattering the seeds.

Plants possibly do not evolve structures for the benefit of any living thing but themselves; and if this is so one might imagine that the reason why the pulp of so many fruits is eatable and palatable is to form an attraction to some fruit-feeder, as the result of which, having satisfied his own palate, he will drop the seed at a distance from where he gathered the fruit. Evidently for the same reason the covering of the actual seed itself in many of these fleshy fruits is much too hard to be either changed during mastication or digested if swallowed; and such

WOOL CONTAINING VARIOUS HOOKED SEEDS

seeds, being carried within the bodies of animals, are ultimately scattered abroad with the excrement of the creature. In this category come such fruits as the fig and the currant, whilst in the former we may mention the peach and the date.

In the cases just mentioned, from the sticky burr to the swallowed currant-seed, the part played by the animal was either unconscious or, at any rate, not deliberate. But there are other instances in which animals purposely carry about seeds, probably in order to store them up for future food.

When a thing like this happens it is usually the fleshy part of the whole fruit that is devoured, and the actual seed, which contains the embryo, is left. So ants carry away seeds thus provided with a fleshy covering, and some of these seeds appear to be constructed as if of set purpose for the ant to handle. Similarly, too, our squirrels store up nuts and acorns in different places as a provision for winter food, but quite frequently they forget where they have put them, and thus become unconscious scatterers of the seed itself.

A still further refinement of a similar adaptive plan is seen in succulent fleshy fruits extremely bitter to the taste until such time as the true seed is ripe within. Then they become attractive to the animals that play the part of distributing agents. The orange is a case in point.

From the foregoing preliminary statement as to the chief methods adopted by plants to disperse themselves, it will be realized that foremost among these methods must be placed those which either in one way or another have reference to the disposal of the fruit. We may therefore at this point pay a little attention to the fruit of plants strictly from this point of view, reserving to a future occasion other interesting aspects in the study of fruits.

The fruit arises from the flower or flowers of a plant and sometimes the adjacent parts after the process known as fertilization is completely finished. It will be enough if we realize at this stage that a pollen grain grows and enters what is to become the seed. It produces a sperm cell which unites with an egg-cell inside the ovule, as the result of which the ovule itself may ripen and become a seed. Now, the term "fruit" means a great deal more than the mere seed itself.

Botanists state that a fruit is a ripened ovary and the parts which adhere to it. The ovary is the ripened lower part of the pistil of the flower and contains the seed or seeds. In a strawberry fruit, then, the fleshy part which we enjoy is the ripened receptacle which bears over its surface the small, dry ripened pistils each of which contains a seed.

In the case of the apple the part which we ordinarily eat is the very much enlarged receptacle which here has grown around the ripened pistil or core which, as you know, contains the seeds. All of these variations naturally lead to variations in the methods of dispersal.

Some of the coverings of the pistil, when they attain full ripeness, open with a spring-like movement, sudden in its onset, having more or less explosive force, as it were, sufficient to scatter the seed to a distance of two or three feet from the plant.

SPORES OF ALGÆ SCATTERED IN THE SEA

This mode of dispersal may be seen in many of the ripe pods of the leguminous plants, such as the peas and beans. In them it may be observed that, after the pods have burst, the valves within them quickly twist themselves up.

But inasmuch as the wind and currents of air are the most potent factors in the dispersal of seed, it is natural to find that the great majority are sufficiently small in size and light in weight to be easily carried for a considerable distance in the wind. There are, however, special adaptations to assist in this process. For one thing, many seeds are quite round in shape, which enables them to be easily moved along a sufficiently smooth surface by any propelling force acting as wind does.

More effective and more striking are the special structures frequently found attached to the seed or fruit, which enable it to sail through the air more or less like a parachute. We have already referred incidentally to the clump of fine hairs acting in this way in connection with the fruits of the thistle and the dandelion. The fruits of these plants, by means of the modification mentioned, are enabled to spread themselves over immense areas of ground, and to be carried for enormous distances.

THE WINGED FRUITS OF THE MAPLE

Very remarkable, too, are the structures, looking like wings, which are seen in the case of the fruits in the ash, the elm, the sycamore and similar plants. The seed in these cases is a fairly heavy structure, and if allowed to fall will do so almost vertically, even though its wings cause it to flutter. But if we watch what happens we shall observe that these fruits, or seeds, are more frequently detached from the trees when the wind is of a very considerable velocity or force. Then the wing-like apparatus with which they are furnished assists in their being carried through the air for a long distance.

With regard to the part played by animals, too, we find in many of the umbelliferous plants, such as the carrot,

special structures in the form of spines, or hooks, that cause the fruits to adhere very readily to the covering of any animal they come in contact with. Ultimately, they are rubbed off the animal's coat, often at a considerable distance from their place of origin.

We have already referred to the dispersal by animals of the seeds which lie within the fruits they eat, these seeds passing through the alimentary tract of the body without being injured. This involves some special form of protection against the digestion of the embryo within the animal's stomach. So we find that in these cases there is a very hard, dense pericarp, or fruit-covering. This structure, the pericarp, is sometimes the attractive portion to the animal. For instance, in the group of berries, like the cherry and the plum and so forth, the pericarp itself forms the attraction to the animal.

In what we popularly speak of as the stone-fruits, there is a hard covering within, the endocarp, which quite effectively prevents any digestive process injuring the seeds while in the body of an animal. These firm, hard coverings will persist for a very long period of time, enabling the seed to be preserved until chance, or design, brings it into such an environment as stimulates it into new growth. Then the protective coverings disintegrate, and the embryo, having passed unscathed through winds and waters, and even animal bodies, is enabled to bring forth a new individual, possibly thousands of miles from the spot where the fruit was produced.

Some special examples of modifications which play a part in plant dispersal

An interesting arrangement of the spread of some lowly plants is that seen in connection with the formation of what are spoken of as fairy rings. These occur frequently in meadows and under trees. Some of the fungi produce very picturesque results. The first growth in the region of a ring is made by the fungus. The food consumed by that year's growth cannot, of course, be used the following year, so the fruit bodies appear around the area occupied by the first growth. The following period of growth is still further out and so on until finally a more or less definite ring appears. The original fungus is all the time moving outwards in a larger and larger circle, into the region where the food has not been exhausted and so the ring gets bigger. Country folks used to associate these ring-like patches with the dances of fairies, or elves, or witches, and popular superstition in some countries attributes their origin to dances by the fairy folk on the night of the 1st of May.

Other fairy rings are formed by plants which send forth underground runners, the growth dying in the middle, but extending peripherally. Thus, distribution of plants by offshoots frequently produces an area of distribution of a circular shape, becoming larger and larger. Of course, it is necessary that the original plant should die, that its growing points should radiate outwards, and that the successive plants should also die, leaving only the living ones at the circumference.

Just as some plants distribute themselves in circles, so do others in more or less straight lines; and this latter formation is the result principally of roots that run horizontally under the soil, and give off buds at intervals. The long connecting root may die here and there, leaving these new individual plants growing more or less in a straight line. The raspberry is a plant which conforms somewhat to this arrangement. A group of raspberry plants moves about three or four feet every year; and so it often happens that raspberries planted near a hedge or fence may, in the course of a few years, be growing quite well on the other side of the fence (possibly owned by someone else), while the original plants have entirely died out.

Dispersal by means of underground tubers is sometimes wonderfully fast, and gives rise to quite large colonies, which gradually spread over a larger and larger area. This sort of process is well seen in the artichoke, whose colonies may be regarded as being arranged in clusters.

The rapidity of the spread in such cases as this will depend upon the length of the underground growth, and the nature of the soil.

The extraordinary rapidity of the dispersal of a plant over an area of ground by means of offshoots on runners is well seen in the strawberry, as described by the Austrian botanist Anton Kerner:

"Suppose a strawberry stock sends out three runners during the summer: each takes root at five nodes, and from each node a bud — *i.e.*, an offshoot — develops, so that the following year the mother-stock is surrounded by fifteen daughter-plants. It should be noted that the length of the internodes in each runner is unequal. For example, in one which had extended over the ground in the shade of the wood, the first internode was 37, the second 34, the third 31, the fourth 30 and the fifth and last 22 cm.; thus the offshoots were the closer together the greater their distance from the mother-plant. Next summer fifteen new offshoots were again formed from each of the original fifteen, arranged in exactly the same way; and in the forest glade, where two years previously there had been only a single strawberry plant, occupying a space of 50 sq. cm., there would now be 200 plants distributed over a space of about 3600 sq. cm."

Of course, when plants change their position merely by sending out offshoots in one direction or another, while they themselves die in an opposite direction, the actual range of distribution is naturally restricted. It is, however, very much increased when we have to deal with plants whose offshoots become separated from the parent stalk, and can be transferred by any of the agencies of wind, water or animals to fresh pastures. In this way the range of distribution of a plant may be extended in a very few minutes over an area which would take many years to cover by ordinary runners. On the other hand, it is not so certain a means of survival, because the detached offshoot may land in an unsuitable environment, but, considering the number of shoots provided for such a purpose, the object is usually successfully attained.

Very few plants produce special organs which enable their shoots to move about on their own account, and when these do occur it is only in the lowly plants which inhabit water. Many, however, are carried passively by water, such as the green algæ, those slimy masses we often see on a sluggish pool, or covering the surface of submerged stones. These plants detach portions of themselves freely, and each portion starts a new growth in a new place. No simpler means of distribution could be conceived.

The seaweeds, and similar plants, appear to owe their distribution mainly to the force of circumstances. Portions of them are torn asunder during the high tides and rough weather, and carried hither and thither until they are deposited into spaces between rocks and stones, or in sand, where a large proportion of them may start fresh growth.

FUNGUS FORMING FAIRY RINGS

THE ONLY BIRD MONUMENT IN THE WORLD

In the summer of 1848 the early settlers in Utah were saved from starvation by great numbers of gulls which flocked to their fields and consumed the swarms of "crickets" which threatened to destroy all their crops. This handsome monument was erected in Salt Lake City to commemorate the incident.

The illustrations in this chapter, except this one, are all from photographs by A. A. Allen.

BIRDS AS MAN'S HELPERS

What They Do for Us and How We Can
Attract Them about the House and Garden

OUR FEATHERED ALLIES IN AGRICULTURE

IN Salt Lake City stands a granite column surmounted by a great sphere with two gulls of gilded bronze just alighting. The square pedestal bears four historical bronze plaques in high relief, and is surrounded by a fountain forty feet in diameter, in which water lilies grow and where song birds come to drink and bathe. It was erected to commemorate an incident in the summer of 1848 when the early settlers were saved from starvation by great numbers of gulls which flocked to their fields and consumed the swarms of "crickets" which threatened to destroy all their crops. The monument is unique. Still in a larger sense, the whole verdant world with its green trees and rich harvests is a monument to the thousands of insectivorous birds that have unwittingly labored for humanity against the millions of insects.

Every year hundreds of thousands of children are enrolled in bird clubs or bird study classes. They constitute a monument of a different sort, expressive of the love and interest that mankind bears toward birds irrespective of their economic value. Indeed the bright colors of birds, their cheerful songs, their many interesting ways seem so apart from the turmoil of everyday life that we have come to look upon bird study and bird protection as having little bearing upon the economy of our existence, little influence upon successful agriculture.

Let us, therefore, forget for the moment that there is anything of interest in birds, that their presence in any way affects our health or happiness, and consider them only from a strictly economic point of view as they affect food production.

With this in mind we shall recognize five main groups of birds: (1) those that destroy insects; (2) those that destroy weed seed; (3) those that destroy small rodents; (4) those that serve as game; and (5) those that serve as scavengers.

The value of birds as destroyers of insects is so well recognized today that little need be said here. The United States and Canada have long recognized the necessity of encouraging insectivorous birds and have passed laws giving them absolute protection. Indeed it has been stated by a former chief of the United States Biological Survey that: "Without the birds not only would successful agriculture be impossible, but the destruction of the greater part of the vegetation would follow."

From the white grubs that live in the soil and cut off the roots of plants to the moths that flit over the tree tops, there are thousands of different kinds of insect enemies insidiously working and threatening to destroy the crops, the trees, the gardens, the very handiwork of man. But for each type of insect nature has devised certain birds which serve as a natural check upon their increase. There are the snipe and woodcock that probe the loose soil, the larks and the sparrows that scratch among the dead leaves and grasses, the warblers and vireos and wrens that scrutinize the foliage, the nuthatches and creepers that search the bark, the woodpeckers that drill for the borers, and the swallows and flycatchers that guard the air itself. Where insectivorous birds are numerous, it is a lucky insect that escapes, but where birds are scarce it is a fortunate plant that completes its life cycle in safety.

The second group of birds consists of those which derive all or a large part of their food from the seeds of weeds. Some of them, like the tree sparrow and snow bunting, nest in the far north and are with us only during the winter months. Others, like the blackbirds and many of the sparrows are with us from early spring until late fall and feed upon seeds except during the nesting season. A conservative estimate of the seeds consumed by the tree sparrows alone each winter in New York State only has placed the total amount at over 900 tons. When, for one reason or another, a large number of seed eaters concentrate on a small area, they undoubtedly have a very beneficial effect on the weed pests of that region, but they would have to be ten times as numerous as they are to have any general effect on the annihilation of weeds the country over.

ONE OF MOTHER NATURE'S RAT TRAPS
A great horned owl and his prey.

HUNTING CANVASBACKS
Some birds serve best as game.

The third way in which birds serve man is by the destruction of small rodents. Nearly every year during the deep snows, thousands of fruit trees, up to six and seven years of age, are girdled by meadow mice. At other times of the year the damage to grains and vegetables by rats and mice can hardly be estimated. These small rodents have from five to seven litters a year and from five to ten young at a litter. If all the young mice should live it would take less than five years for the offspring from each pair to number over three million. It is therefore necessary to have some natural control upon their numbers, and nature provides this in the hawks and owls. Indeed there are certain owls which regularly travel in flocks and seek out regions where the mice have become especially abundant, and they remain there until they have reduced them to normal numbers. Only one species of owl, the great horned owl, occasionally makes a nuisance of himself around the poultry yard or game farm and three species of hawks, the Cooper's, sharp-shinned and goshawk, regularly feed upon birds and poultry and should be done away with, but this is no excuse for putting all species under the ban, or for placing bounties upon their heads, as is often advised. We can afford to lose a few chickens and a few valuable birds rather than to be continually overrun with rats and mice and ground squirrels.

The fourth group of birds are those which serve man best as game. Every year in New York State alone nearly 300,000 persons take out hunting licenses and the value of the game taken is over three million dollars and yet New York State is not noted for its game. There was a time not long ago, when any bird that was large

ALLIES AGAINST AGRICULTURE'S FOES

BOBOLINK
With army worm for its young.

YELLOW-BILLED CUCKOO
With tent caterpillar for its young

DOWNY WOODPECKER AT WORK

A TREE SPARROW IS A WEED DESTROYER

enough to eat was considered a game bird and large numbers of robins, meadowlarks, flickers, killdeers and other insectivorous birds were sold in the markets. Today we realize that these birds serve man far better as destroyers of insects, and we limit our game birds to pheasants, grouse, quail and waterfowl which serve best in this capacity. As the number of hunters increases and the natural game covers decrease, the law makers and naturalists are presented with a new problem, that of maintaining the game supply against

ONE OF MOTHER NATURE'S SCAVENGERS
A turkey vulture sunning himself.

great odds. But laws alone cannot create game, and the business of producing large numbers of game birds either by properly maintained reservations or by game farms is becoming increasingly important.

The fifth way in which birds serve man is as scavengers. The turkey vulture and the black vulture of the south, commonly called "buzzards", are ever present when carrion is to be disposed of and even a snake cannot die without being promptly discovered by them and devoured. In the north the crows and gulls perform a similar service in keeping dead animal matter from polluting the air. Especially about our harbors and shores are they needed, where the refuse from cities is thrown and where dead fish are continually thrown up by the waves, but they likewise often feed together long distances from water if a carcass is discovered that has not been properly cared for.

These five services which birds render us can scarcely be overestimated, but we are interested in birds not only for the good which they do but for the pleasure which they bring into our lives. Let us therefore consider the several means by which birds may be attracted to the house and garden.

One of the simplest ways of attracting birds about one's home is by feeding them in winter.

The winter birds that may be expected to come to a feeding shelf are of two kinds — seed-eaters and insect-eaters. Among the seed-eaters in northern United States are the junco, the redpoll, the pine siskin, the crossbills, the grosbeaks, the song and tree sparrows and the blue jay. In southern United States one could also expect the white-throated, white-crowned and fox sparrows, the blackbirds and the cardinal, and in the Western States other species of finches and buntings. For seed-eating birds, good foods to use are millet, hemp, buckwheat and cracked grain of any sort, or, better still, mixed chicken feed, such as is sold for young chicks, sweepings from a neighboring mill, or hayseed from the barn floor.

Among the insect-eaters are the woodpeckers, the downy and hairy woodpeckers very widely distributed, the flicker, red-bellied and red-headed more common southward, the nuthatches, the chickadees and the brown creeper. The woodpeckers find their natural food by drilling into the chambers of wood-boring larvæ, the others find insects, pupæ or eggs in the crevices of the bark. All of them, however, are very fond of beef suet, and once they have found a piece fastened in the tree, they will return to it again and again until it is all gone. Sunflower seeds and crumbs of raw peanut are relished by both insect and seed-eating birds.

In placing the food it is well to bear in mind that eventually one wants all the birds coming to one place, either at a shelf at the window or to a place in the yard where it will be easy to watch them. It is well to select first the place where one wishes them to come, whether one immediately builds the shelf or not. Then, from this as a center, place the food along radiating lines to a considerable distance from the house. The more pieces of suet put up, the more quickly the birds will find it, and the sooner they will come to the window sill, for birds are ever on the alert watching their fellows as well as searching for food on their own account. When one bird finds the suet, the others will see him and soon follow.

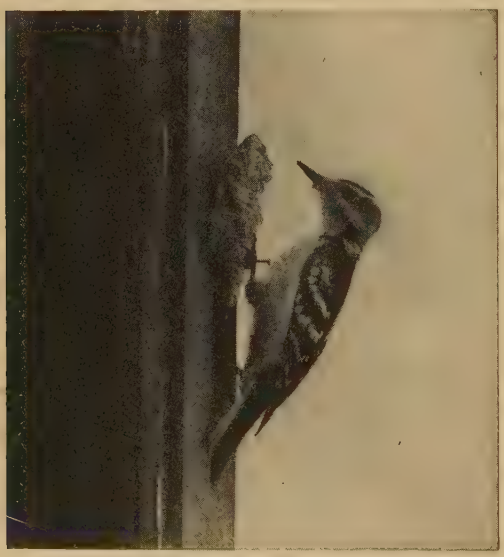
After the birds have found the suet it will be more economical to cover it with a piece of wire screening (one-half inch mesh) through which the smaller birds can peck. This precaution will keep the squirrels and crows from imposing upon one's hospitality and carrying the suet away in one piece. Another method is to suspend from the outer branches, by strings, small wire or twine baskets filled with suet. These baskets can easily be made from an ordinary piece of wire, as the size and shape are not important. Instead of using wire, some persons prefer to use a bag knitted from string and of such coarse mesh that the birds can easily peck through it. A half of a cocoanut shell makes a very satisfactory basket.

As soon as any of the birds have been seen eating the pieces of suet, it is time to put up the feeding shelf. This should be placed at a window on the sheltered side of the house (usually the south), preferably the one nearest to a tree. If the window sill is very broad, it will be sufficient to nail a cleat along the outer edge to keep the food from blowing off. Usually, however, it is more satisfactory to fasten a board, from eight to twelve inches wide, to the sill to act as a shelf. It may be made the entire length of the window sill or only a part; but the larger it is, the more birds will feed together, for our native birds all want plenty of elbow room while

"WHEN A FELLER NEEDS A FRIEND"
Juncos, seed-eaters, waiting to be fed during a snowstorm.

feeding. A narrow strip should be fastened to the edge of the shelf to keep the food from blowing off. At the westerly end a small evergreen tree or a large branch should be fastened. This offers shelter to the birds and proves as attractive as the food itself. It may be nailed to the window casing, or a hole may be bored in the shelf to hold it. It should be as large as can conveniently be held in place.

An even better device than the window shelf is the window feeding box. An ordinary soap box can be used and the bottom replaced by a pane of glass so as to admit plenty of light. One side is then rested on the window sill and the inner end



SUET ATTRACTS INSECTIVOROUS BIRDS
A hairy woodpecker on the window casing.

nailed to the casing, while the closed glass side faces the north and the box opens to the south. This box has the advantage of protecting the food from the snow and ice so that it is always available when most needed. Evergreen branches or a small tree fastened near by will increase its attractiveness. In many places house sparrows are so numerous that they will consume all of the food as fast as it is put out and leave none for the native birds so that it is necessary to find some way to curb their enthusiasm. A very simple yet effective way of protecting the food from their depredations is to hinge the front half of the floor of the box and support it at the corners by weak springs so that when a bird alights it bounces up and down. House sparrows are naturally so suspicious that when they feel the shelf give way beneath them, they lose no time in getting out of the way and never stop long enough to get any of the food. Our native birds, on the other hand, are unsuspicious and accustomed to feeding about the swaying branches of trees so that the more the shelf bounces, the more they seem to like it.

In case there is not a satisfactory window at which to feed the birds, this box can be placed on a post in the yard four or five feet from the ground. An evergreen tree, a bit of shrubbery or a pile of brush should be in the near vicinity to serve as a way station from the nearest trees, as most of the birds hesitate to fly long distances through the open, even to get food.

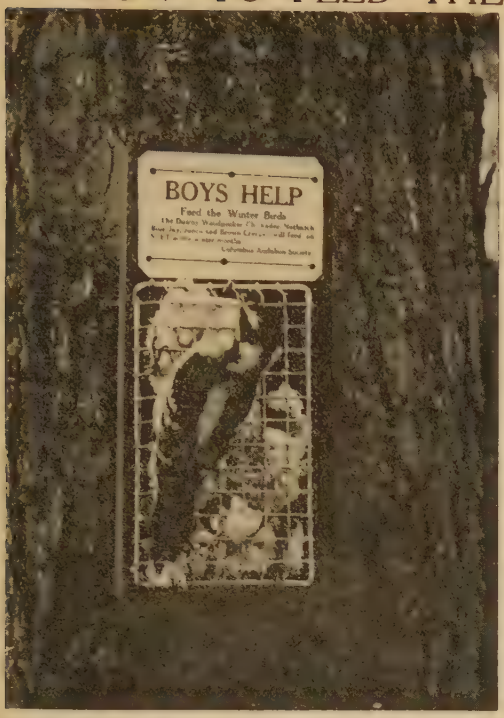
Another simple form of feeding shelf for such a place in the yard is made from the top of a keg or barrel, protected from the weather by a hood improvised from barrel hoops and a piece of white cloth and covered with a few evergreen twigs as here illustrated. The front half of this may likewise be hinged to keep away the sparrows, and it may rest on a pivot and be provided with wings like a weather vane so that it will always face away from the wind and snow. Various modifications of this device will undoubtedly occur to the reader.

If nothing but sparrows come to be fed, one should not be discouraged because they will act as decoys, and eventually their chirping will call other more desirable birds to the feast. One need not fear that they will drive the other birds away, for, next to the chickadee, the sparrow is the biggest coward of the lot, and often a single nuthatch will put a whole flock of them to rout.

Another method of feeding birds is to plant patches of millet, hemp, buckwheat or sunflowers along the edge of the garden and let the birds do the harvesting.

Many hardy shrubs, vines and trees bear fruits which are attractive to birds and should be planted wherever birds are desired. The number of birds which depend upon fruits for their sustenance during part of the year, at least, is surprisingly

HOW TO FEED THE FEATHERED FRIENDS



CONVENIENT SUET HOLDER MADE FROM A SOAP DISH

THE WINDOW FEEDING SHELF AND BIRD'S CHRISTMAS TREE

ANTI-SPARROW WINDOW FEEDING BOX

EFFECTIVE HOME-MADE FEEDING TABLE

large and includes birds of almost every type from the woodpeckers to the thrushes, even the warblers, vireos and flycatchers being fond of some varieties.

In planting to supply fruit an effort should be made to select trees and shrubs with different fruiting periods, so that the supply will be more or less continuous.

If nothing but mulberry trees were planted, for example, the birds would have a surfeit during June, July and August, but would starve during September and October. If wild black or bird cherries are added, the birds will be provided for until November. The Virginia creeper and wild grape will hold their fruit through the entire winter, and the hackberry, the sumacs and the barberry practically throughout the year. These last mentioned, while not so attractive in the fall, when other fruits are available, are often the means of saving birds during the storms of early spring.

A strong argument in favor of planting the wild fruits is that of protecting the cultivated varieties. In some places the robins and waxwings do much damage to cherries, the catbirds and thrushes to berries, and the warblers to grapes, but in every case it is because there are insufficient native fruits in the neighborhood to supply their needs.

Below is appended a list of woody plants suitable for attracting birds. Those unmarked bear fruit relished by birds; those bearing an asterisk furnish also satisfactory nesting sites. The list is not complete, but even a superficial inspection of it will show how one may very easily select a wide range of shrubs and trees suitable for almost every kind of planting which will at the same time attract birds by their fruits and by the shelter which they afford. Care should be used to select none which would serve to spread fungus diseases, even though they may be very attractive to birds. The various species of currants and gooseberries (Ribes), for example, which are often highly recommended as supplying bird food, have been omitted from the list because they assist in spreading the dreaded pine blister. In wheat-raising districts, the barberry should be avoided likewise, because it harbors the intermediate stage of the wheat rust.

FRUIT-BEARING TREES AND SHRUBS ATTRACTIVE TO BIRDS

* Five-leaved ivy or Virginia creeper, August–February
Boston ivy, September–March
Red and black chokeberries, July–June
* Spicebush, July–November
* Japanese barberry (the berries are not often eaten when other fruits are abundant, but the shrubs furnish good nesting sites)
* Common barberry, July–June
Black or cherry birch
Yellow birch
White birch
Red birch (all the birches furnish food in fall and winter except the red or river birch, the fruit of which ripens from June to September)
Hackberry, January–December
* Dogwoods, June–March
White flowering dogwood (very desirable for its ornamental value, both in flowers and in fruits, as well as for bird food), August–January
Cornelian Cherry
* American hawthorns, October–April
* English hawthorn, August–March
Weigelia or Diervilla (the seeds are freely eaten in winter by slate-colored juncos, tree sparrows, redpolls and pine siskins)
Oleaster or wild olive, September–April
Gumi
Japanese oleaster (as soon as the fruit ripens in July it is attacked by robins, catbirds and cedar waxwings, and the tree is soon stripped)
Spindle tree (fruits are eaten by the myrtle warbler)
Wintergreen, January–December
Black huckleberry, July–October
Shrubby St. John's-wort (in winter slate-colored juncos, tree sparrows and redpolls are always found feeding on the minute seeds of this plant)
* Common juniper, January–December
* Irish juniper
* Red cedar (a favorite food of cedar waxwings and myrtle warblers), January–December
American and European larches
* Common privet, July–April
* Bush honeysuckles
* Japanese honeysuckle
* Morrow's honeysuckle (very attractive to birds)
* Ruprecht's honeysuckle
* Grapes, August–June
* Tartarian honeysuckle, July–April
* Matrimony vines
Partridge berry, January–December
Mulberries (one of the best bird foods), May–August
* Bayberry, or candle-berry (the best food to attract and hold the myrtle warblers), July–June
Sour gum or tupelo, July–October
White, black and Japanese spruces

CHICKADEE CONTEMPLATING AN INVESTIGATION
Sunflowers attract the chickadee, nuthatch and goldfinch.

ROBINS FEEDING AMONG THE VINES
Virginia creepers attract many birds during the fall and winter.

FEBRUARY ROBIN TOO EARLY RETURNED
The sumach saves the lives of robins and bluebirds that come north too early.

WAXWING ON A MULBERRY BRANCH
Mulberry trees protect the cherries from fruit-eating birds like the waxwing or "cherry bird".

Austrian pine, Red pine, White pine (All the pines attract crossbills and grosbeaks)
Mahaleb cherry (the best of the wild-cherry bird foods), June–July
European bird cherry
Wild red or bird cherry, June–November
Sand cherry, June–August
Wild black cherry, July–November
* Flowering crab (the best winter food for cedar waxwings, robins, northern flickers, pheasants and pine and evening grosbeaks), September–June
* Buckthorn, August–April

AN ATTRACTIVE BIRD BATH IN A GARDEN

Fragrant sumac, January–December
Shining sumac, January–December
Smooth sumac, January–December
Staghorn sumac, January–December
* Blackberries and raspberries, June–October
* Black elderberry, July–October
Red elderberry, June–August
Sassafras, July–October
Buffalo berry, June–October
* Greenbrier, August–June
Nightshade, or bittersweet, July – April
Mountain ash (as the bright red berries hang on the trees, about Christmas time, these trees add to a winter landscape by their ornamental appearance. They also furnish very good bird food), July–April

Another method of attracting birds about one's garden is to have convenient for them a constant supply of fresh water. This may be offered in an elaborate bird fountain or bird bath built to correspond with other architectural features of a formal garden or it may be merely a shallow pan of water which is replenished from time to time. The principal thing to bear in mind is to place it so that the birds will not fall victims to preying cats when they are almost helpless with their soaked plumage.

Still another way of attracting birds about one's home is to build bird houses which are suitable for them to nest in.

There are over fifty species of birds in the United States and Canada which utilize holes in trees for nesting, including many of the most useful. The borer-destroying woodpeckers, the larvæ-destroying nuthatches, the egg-destroying chickadees, the mosquito-destroying tree swallows — all build in holes in trees and may be attracted to nesting boxes. In these days of scientific forestry when every dead tree is condemned and when every dead branch is lopped off by the "tree doctor", the birds' natural nesting sites are rapidly disappearing and their numbers must necessarily decrease unless they are provided with artificial nesting places. It is a wise timber owner who puts up at least one nesting box in the place of every dead tree which he removes. The chickadees and woodpeckers that are with us in winter and the wrens and bluebirds that return in the spring will move on unless they find plenty of nesting sites.

Of the hole-nesting birds, a comparatively small proportion have yet learned to accept the artificial nesting site, only nine species taking them regularly and nineteen more utilizing them occasionally. It is to be expected, however, that eventually all the species will learn to adapt themselves and perhaps even others will so modify their present nesting habits as to accept the artificial structures. This proved to be the case in the celebrated experiments of August von Berlepsch in Germany, where out of a thousand nesting boxes on his estate, birds gradually were induced to occupy over 900.

The species which regularly use nesting boxes are as follows: house wren (and all its sub-species), bluebird (eastern and

western), chickadee (northern and southern sub-species), purple martin, tree swallow, flicker, violet-green swallow, house-finch, Bewick's wren, house sparrow, and starling.

The species which occasionally use nesting boxes are as follows: white-breasted and red-breasted nuthatches, downy, hairy and red-headed woodpeckers, tufted titmouse, Carolina wren, crested flycatcher, screech, saw-whet and barn owls, sparrow, hawk, wood duck, song sparrow (rarely), and dipper. The species reported as using covered shelves or shelters, open at the sides, are robin, phœbe and barn swallow.

The best materials to select in building bird houses are weathered boards, rustic cedar, slabs of wood with the bark adhering, or asphaltum roofing paper. Smoothly planed boards and paint should be avoided except on such houses as are intended more for ornament than for use. Gourds, when obtainable, can be made very acceptable by cutting a hole of the proper size in one side, cleaning them out and drilling a small hole in the bottom to drain off any rain that may beat in. A hollow limb, a deserted woodpecker's nest, or a block of wood hollowed out in the form of a woodpecker's nest are all good devices, but usually it is easier to cut rough boards into proper lengths and nail them together securely in the form of a small box. Sometimes boxes of the proper size, such as chalk boxes or starch boxes, can be found ready made and require only some reinforcement. If one plans to make a great many of standard size, heavy asphaltum roofing paper lends itself most readily at a minimum of expense.

Whatever material is used the exact size of the box is not of great importance except that it should not be so large as to waste material, nor yet so small as to give insufficient room for the nest. A box should never be smaller than $3\frac{1}{2}\times3\frac{1}{2}\times6$ inches inside measurement, and it is better to make it somewhat larger even for wrens. In making bird houses for the first time, it would be well to make them of average size, that they will be acceptable to the greatest variety of birds. In this way the chances of attracting them are increased. Such a box would measure about $4\times4\times9$ inches inside with the long axis vertical. If special effort is to be made to attract flickers, screech owls or sparrow hawks, boxes $6\frac{1}{2}\times6\frac{1}{2}\times24$ inches should be made. If purple martins are desired, a house of from 10 to 30 compartments should be constructed with each compartment 6 to 8 inches square. Rows of gourds tied to cross pieces and raised on poles will likewise attract martins and are extensively used in the South.

TAMING A CHICKADEE

The *size* and *position* of the opening are much more important than the exact size of the box. A round hole is best and, except in martin houses, it should be cut above the middle line on one side only, and preferably about two inches from the top. All hole-nesting birds, except the martins, wish to be out of sight of the entrance while incubating. There should never be more than one entrance to the box, but if the box is very tightly built a $\frac{1}{4}$ inch hole may be drilled just beneath the roof for ventilation and another through the floor for drainage. These are unnecessary, however, and in natural nesting cavities, of course, never occur.

If one wishes to build houses for certain birds, the following table of proper diameters for the openings will be found valuable:

a. $1\frac{1}{8}$ inches: house wren, Bewick's wren, Carolina wren, chickadee.
b. $1\frac{1}{4}$ inches: white-breasted nuthatch, tufted titmouse.
c. $1\frac{1}{2}$ to $1\frac{5}{8}$ inches: bluebird, downy woodpecker, crested flycatcher, tree swallow, violet-green swallow.
d. $1\frac{3}{4}$ to 2 inches: red-headed and hairy woodpeckers.
e. $3\frac{1}{2}$ inches: flicker, saw-whet owl, purple martin.
f. 3 inches: screech owl, sparrow hawk.
g. $4\frac{1}{2}$ inches: barn owl, wood duck.

Nesting material

No nesting material in the form of straws, feathers or sticks should be placed in the box, since, if a prospective tenant finds nesting material in the box, he will usually consider it already occupied and move on. In flickers' and other woodpecker boxes, however, there should be placed in the bottom a couple of inches of ground cork or coarse sawdust mixed with a little earth because the woodpeckers build no nests and must have something to keep the eggs from rolling about.

Quite as important as the proper construction of the bird house is the selection of the place to put it. It is possible to put up ten or fifteen boxes and have nothing but house sparrows nesting in them, when, if properly placed, they would be occupied by wrens, chickadees, swallows or bluebirds. If several boxes are put up, they should be at least 25 feet apart and preferably farther or constant fighting will usually result until one of the tenants is evicted. If one examines the natural nesting places of any of these hole-nesting birds, he will find that with few exceptions, they are in open places in bright sunlight or light shade, and seldom among thick branches of a tree or in dense shade. The best place for the box, therefore, is on a pole, five to fifteen feet from the ground in an open space or at the edge of trees facing the open. An iron pipe, an inch or more in diameter and eight feet long, set in the ground two feet, makes an ideal location for a box as it likewise gives protection from cats and squirrels. A post on the porch or the unshaded side of the house will also serve if the box is made to face outward. The trunk of a large tree, several feet below the first branches, a telegraph pole or a high fence post are other places which will prove suitable, although perhaps not quite so satisfactory as the separate post. An excellent place for the large flicker or sparrow hawk box is the top of a dead tree, particularly if the smaller branches are cut away from around the box. Occasionally a wren or a nuthatch will use a box placed in the shade among the branches of a tree but such places, while appealing strongly to most people as highly desirable, should be avoided. House sparrows are the only birds that will regularly use boxes when so placed.

If a box is well made and once in position, it need never be removed, though it will probably last longer if taken inside during the winter. Frail or fancy boxes should be taken in each fall and replaced in March. Cleaning a box is not necessary under ordinary circumstances, as the birds will do their own renovation, but it is well to have the top or one side hinged, so that one can get at the inside if necessary, to throw out the nests of sparrows, or squirrels, or mice, or hornets that sometimes usurp the box before the birds arrive. Aside from this there is little need of care, and at the end of the season the old nests can be thrown out or left in, it making little difference to the birds when they return the following spring. The lice which often infest the nests of wrens are harmless and die soon after the young leave. If anything is to be done, the nests should be sprinkled with insect powder while still occupied.

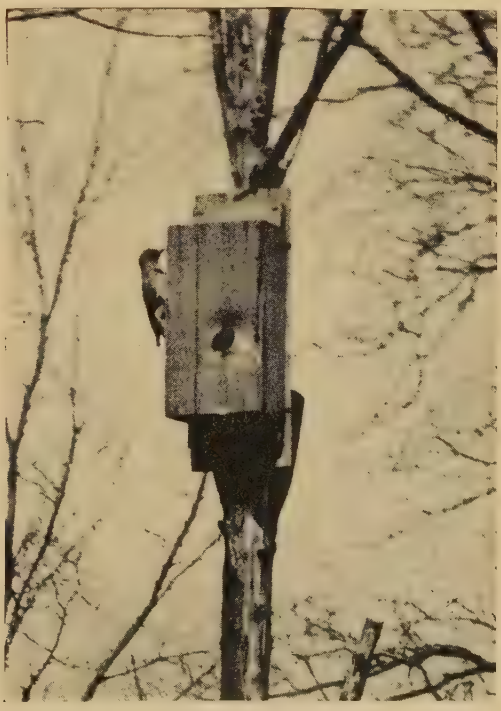
The boxes should be in place as early as possible in the spring, especially those intended for nuthatches and chickadees that are with us throughout the winter. Although they do not begin nesting until April, chickadees often commence excavating their nesting cavities in February and it is probable that they have selected their nesting sites by this time. Boxes put up after the first of March and even as late as the first of May are sometimes occupied the same year but the chances are much better if they are put up early.

NEAT HOMES FOR PLEASANT NEIGHBORS

HOME-MADE WREN BOX WITH $1\frac{1}{8}$ INCH ENTRANCE FASTENED TO THE PORCH

PURPLE MARTINS DRIVING A SPARROW FROM THEIR COLONIAL BOX

BLUEBIRD BOX MADE OF ASPHALTUM ROOFING PAPER



WELL-PLACED FLICKER BOX IN A DEAD TREE

THE TRAVELS OF SOUND IN THE EAR

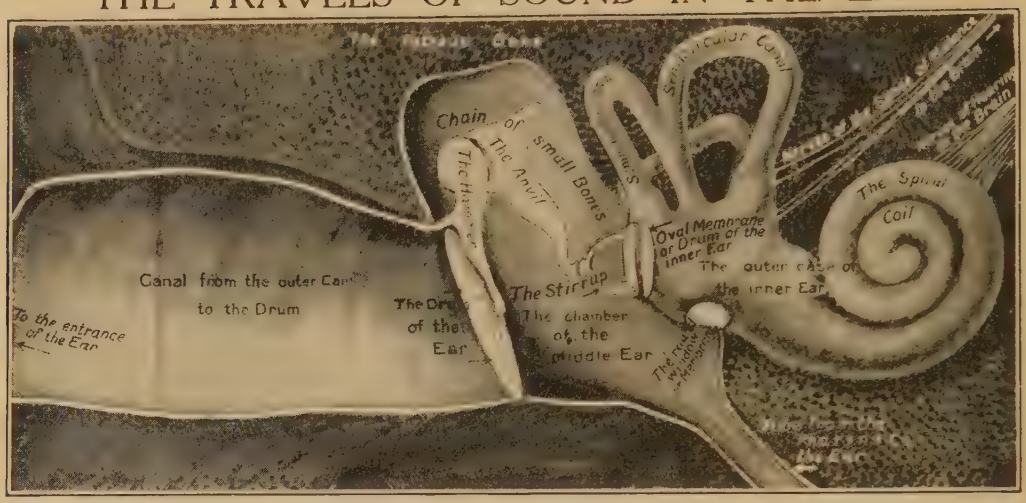
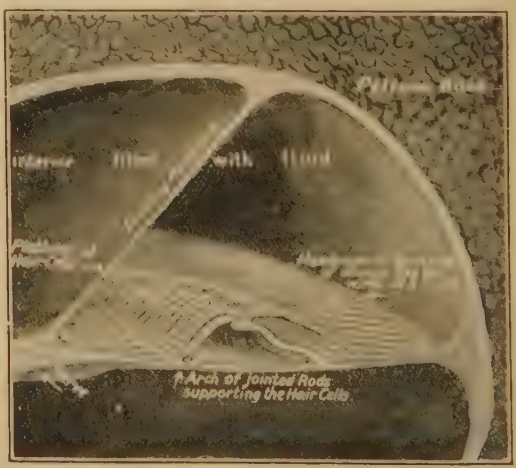

Chain of small Bones
The Anvil
Oval Membrane or Drum of the inner Ear
The Spiral Coil
Canal from the outer Ear to the Drum
To the entrance of the Ear
The Stirrup
The chamber of the middle Ear

DIAGRAM OF THE CHAMBERS AND BONES OF THE OUTER, MIDDLE AND INNER EAR

DIAGRAM SHOWING THE PASSAGE OF A SOUND-WAVE FROM THE OUTER AIR TO THE AUDITORY NERVE

ENLARGED SECTION OF PART OF THE COCHLEA, WITH THE RECEPTIVE NERVES IN DETAIL



SECTION OF THE COCHLEA SHOWING THE INTERNAL DISTRIBUTION OF THE NERVES

THE WONDERS OF THE EAR

The Marvelous Adjustments of the Ear
for its Multitudinous and Delicate Uses

DO WE THINK THROUGH SIGHT OR HEARING?

ON every ground we are justified in dividing the senses into higher and lower, and there is no doubt that vision and hearing stand together, with never a third, in the first category. They are higher because they are of later evolution. Probably all the qualities of sensation have been slowly evolved, in the immeasurable past, from some primitive obscure quality of sensation more of the nature of touch or pressure sensation, or perhaps from two qualities, one aroused by pressure and the other by chemical agents — this latter being the ancestor of modern taste and smell. Hence touch, taste and smell as we have them are historically more primitive in type than vision and hearing.

The question, like all questions in this realm of psychology, is of some æsthetic and ethical importance, for the claim is sometimes made that all the senses are necessarily of equal rank, and that therefore the pleasure of the palate, for instance, by the art of cooking, or the cultivation of the olfactory sense in certain decadent individuals, must be reckoned as on a par with the pleasures of painting and music.

To this the reply is that, historically considered, the senses are not equal. Nor are they equal when considered from the standpoint of their capacities. We must regard as higher those senses which have a great variety of possible qualities, and which afford us the largest measure of information about the external world, or of communication with our fellows. Thus judged, sight and hearing are obviously far higher than, say, the temperature sense, which has a very small variety of qualities, and affords us a very limited range of information.

Nevertheless, there is no doubt as to the very simple beginnings of the highest senses. Vision, with its infinite perceptive and creative possibilities, begins in simple sensibility to light, such as we find in many of the lowest forms of life. But living organisms have made incalculable use of this primitive capacity, until, in the highest animals and in ourselves, they have developed, as we have seen, special structures which not merely appreciate light, but can distinguish between the qualities of light of all colors. This subtle discrimination of color, achieved by means of the recently developed cones of the human retina, marks the level to which the primitive sense of light has attained.

There is here a close parallel with the ear and the sense of hearing. Historically, and even today, that may be called a pressure-sense. The physicists tell us that sound is simply a series of to-and-fro waves in the air, or some other medium, which reiteratedly bang away at the drums of the ears. It is essentially a series of taps, and nothing more. Vibrations made by a very large and heavy tuning-fork will excite waves in the air that may be just too infrequent to be heard, but are readily felt by the skin, and such an observation shows us at once the simple physical and psychological relation between the touch, or pressure-sense, and hearing. Doubtless this pressure-sense must be as primitive and as early developed in the history of life as sensibility to light; indeed, the very earliest forms of life, developed in darkness, must have been sensitive to pressure.

Why the modern hearing is entitled to be grouped with the higher senses

But modern hearing is entitled to be called one of the higher senses, as compared with the primitive pressure-sense which is still illustrated in the surface of the skin, because of the great range of qualities and great powers of discrimination between them which this sense now exhibits. Apparently there is a close parallel between its recent development, culminating in man, and that of vision. Color in light corresponds to pitch in sound. In each case the scale depends upon the frequency of the respective waves. When the eye distinguishes colors it distinguishes wave-frequencies, and exactly the same is true of the ear when it distinguishes sounds. We have seen that the modern eye is marked by its capacity to distinguish colors, and that this depends upon the development of a comparatively recent structure, the cones of the retina. Just so do we find that the appreciation of pitch, upon which the possibility of music, to name nothing less, depends, is a recent development of the sense of hearing, and appears to depend upon the most recent structure in the ear, which is known as the organ of Corti, and is thus the aural parallel to the cones of the retina.

What the ear has lost and gained during its evolution

But in the case of the eye we did not reach the cones of the retina until we had traversed a very complicated apparatus for conduction and control of the waves of light. Similarly, before we reach the organ of Corti in the internal ear, we have to study a sound gathering and conducting apparatus. The ear has no lens by which the sound-waves, can be focussed just like light-waves, but it has an apparatus for gathering sound-waves which comes to much the same thing, and it also has muscular arrangements for controlling the intensity of sound, corresponding to the iris of the eye.

What we commonly call the ear is really simply a gathering device, markedly decadent in man, which cannot be controlled by him either for the better reception of sound or for the detection of its direction. It is true that the external ear is provided with three small muscles, but only a few people have voluntary control of them, and even those persons do not put them to any use. The reflex mechanism which would enable us to "cock" our ears has also fallen into desuetude. This is merely one more of the many instances in which the body of man is decadent, and if we test his hearing quantitatively we may be tempted to regard this sense as inferior in him, compared with many of the lower animals. But, judged by what we have declared to be the only legitimate test, which is qualitative, the human ear is quite incomparable.

The external ear is not entirely negligible, however, for if it be experimentally filled with wax, except for an aperture corresponding to the canal which leads inwards from it, the hearing is somewhat dulled. But if we desire to estimate the direction of sound, we have no machinery now for the purpose, and can only compare the relative intensity of the sensations set up in the two ears. Long and careful experiment has shown that this alone is accountable for our appreciation of the direction of sound. It follows that we cannot distinguish between sounds made at the back of the neck or under the chin, if these be produced when we are blindfolded, for sound coming from such positions is equally well heard in both ears, and we are left without guidance.

The drum of the ear a genuine and designed drum

From the external ear a canal leads inwards until it is closed by a definite and unmistakable drum-head. The canal is lined with glands of a peculiar type, which secrete the wax of the ear, in order to keep the canal clean. The drum of the ear, or tympanum, is no more figuratively so named than the lens of the eye. It is what it is named, and those who can credit its origin by the natural selection of chance variations can credit anything. If this drum be looked at by the aid of a beam of light thrown into the auditory canal, a deep shadow is seen lying across it.

This is due to the first of a chain of three minute bones, the auditory ossicles, which are found in the middle ear. From their form these three bones are called the malleus, incus and stapes — the hammer, the anvil and the stirrup respectively; and they are jointed together as the diagram shows, so that they communicate between the outer wall of the middle ear, constituted by the tympanum, and its inner wall, which has a window, or opening, also closed by a membranous drum, to which the foot of the stirrup is attached.

The peculiar and special dangers of the air-filled middle ear

The middle ear is filled with air, by a special tube which runs from the pharynx. The oxygen from this is absorbed by the blood in the neighborhood and carbonic acid given out by a process of very subsidiary breathing comparable to that which we have seen in the lungs. Not only is this necessary but the pressure of the air must always be the same as that in the auditory canal, so that the drum of the ear having equal pressure on both sides can vibrate freely when sound-waves strike it.

This tube is a physiological necessity, but also a source of danger. It means a possible route of infection from the nose and throat. Thus microbes that have obtained a hold there, as in scarlet fever or measles, are very liable to travel up this Eustachian tube, as it is called, and to infect the middle ear. Short of that, inflammation of the throat is apt to close the Eustachian tubes, and so interfere with hearing, as we know in the case of a common cold. But actual middle-ear disease is a serious affair. It is very apt to lead to the perforation of the drum, an irreparable disaster, and it may involve the thin bony roof of the middle ear, upon which lies part of the brain itself. Hence the Eustachian tube is the route by which an infection of the throat may lead to inflammation of the lining of the brain, technically called meningitis, or to abscess in the brain itself. The practical moral of this is to enforce more attention to the hygiene of the nose and throat, especially in children, so susceptible to adenoids.

Air, bone and fluid each used in the ear as a conductor of sound

Inside the middle ear we find two muscles, one attached to the malleus, and called the tensor tympani; the other attached to the stapes, and called the stapedius. When the former is thrown into contraction it pulls upon the malleus, which is attached to the tympanum, so that the tympanum is tightened and made considerably more responsive to sound-waves striking it. This is the muscle which we throw into action when we strain to hear.

Not less important is the action of the stapedius, which is to damp down the vibrations of the bony chain, so that loud sounds are made less intense. One of the reasons why expected noises are so much less distressing, and why people cheerfully bang the door who resent other people's carelessness, is that the stapedius muscles in the two ears are thrown into anticipatory action. In certain injuries to the facial nerve, which sends a slip to the stapedius, this muscle is paralyzed, and then loud sounds are apt to be very painful — like a bright light thrown into eyes of which the iris has been paralyzed by belladonna or its active principle, the alkaloid atropine.

Apparently these arrangements for the control of sound furnish the chief or only reason for the existence of the middle ear. There is no doubt that the chain of bones through which these muscles act are the efficient conducting arrangement, for hearing is markedly impaired if the bones be destroyed by middle-ear disease, or even if the tiny, delicate joints between them be stiffened in old age.

The sound-waves passed through air in the auditory canal, through a chain of bones in the middle ear, and now they come to fluid, and are conducted in it, so that we actually hear sound-waves in water, as in the case of fish, where only an inner ear is developed. This fluid is contained in the inner ear, which is closed by the membrane to which the foot of the stapes is attached. The whole apparatus lies buried inside the hardest bone in the body: the rocky, or petrous, part of the temporal bone.

This extreme hardness of the temporal bone is probably a very great advantage from the point of view of sound conduction, and sound-waves can to some extent affect the inner ear by conduction from the teeth and through the bones of the head. When the temporal bone is examined, it is found to contain a double piece of apparatus, all of which is undoubtedly of the same evolutionary origin, and which appears to be supplied by one and the same nerve.

This auditory nerve, however, is now known to consist of two distinct parts, with different centers in the brain, but only one of these is really auditory. The other runs to the brain from what are called the semicircular canals, now known to be no part of the organ of hearing. They have a very important function, as we shall see, but it has nothing to do with hearing. Their structure plainly indicates that they are concerned with the direction of something, and the view was long held that they inform us as to the direction of sounds, but that is now known to be erroneous. They are our organs of equilibrium.

The primitive ear in animals which has been further developed in man

In invertebrate animals we find a sac, containing hard material, and called the otolith sac. In the fishes and all other vertebrates three semicircular canals are developed, and the otolith sac is divided into two. From one of these two portions there is developed, in reptiles, birds and mammals a spiral canal, like the shell of a snail, which is called the cochlea. This it is which has taken over, in ourselves, the whole of the function of hearing, and has developed within itself the extraordinary structure which is known as the organ of Corti, and corresponds to the retina of the eye. It is to be admitted, however, that the retina is really nothing less than brain, while the organ of Corti is developed from the surface of the body.

The cochlea consists of two and a half spiral turns round a central supporting pillar. But this spiral canal is subdivided by plates of bone and membrane into three staircases, or scalæ, as the early Italian anatomists called them.

The wonderful vibratory organ of the inner ear

Upon the membranous partition, which extends throughout the two and a half turns of the canal, we find the special structure called the organ of Corti. This is a very complicated arrangement of cells, placed upon a vast number of parallel fibers rather like piano wires, which are longer at the base of the cochlea, and gradually get shorter as the staircase across which they are stretched gets narrower. The resemblance between these regularly shortening fibers and the wires in a piano or other stringed instruments is too striking to be overlooked, and it has been supposed that these fibers act like the wires of a piano, responding to various vibrations that reach them, according to their length, and thus affecting the particular part of the organ of Corti which lies upon them.

In this organ itself the essential elements are the hair-cells of Corti, many thousand in number, which are long, plump cells, having fibers of the auditory nerve encircling their bases, while their upper ends are provided with several short, stiff hairs, bathed in the fluid that fills the cochlea. These are undoubtedly the all-important cells of the inner ear, and are to be looked upon as exactly corresponding to the rods and cones, or perhaps more especially to the cones, of the retina.

Where sound becomes changed to nerve impulses and the brain hears

Whatever may be thought of the resonance or piano theory, which was stated in its original form by the great German Helmholtz, it seems impossible not to suppose that the hairs of the hair-cells must have an important function, since we know that they are bathed in the very fluid in which the sound-waves are certainly transmitted.

Only prolonged microscopic study of the organ of Corti can give any real idea of its complexity, and the completeness of the arrangements which it comprises for the reception of sound-waves. Thus, for instance, there appears to be a membrane which damps down the vibrations after

they have passed the cells upon which they act, and it is also noteworthy that there are no blood-vessels in this organ, for undoubtedly the alterations in the blood-pressure would sadly interfere with hearing if there were. The nerve supply is extremely rich, and the ultimate fibers lose their sheaths and envelop the pointed ends of the hair-cells. It is at this point that we have to face the mystery which we met in the retina. Light goes no further than the rods and cones, and sound goes no further than the hair-cells of Corti. What travels to the brain through the auditory nerve is not sound, but nerve-impulses, and it is a further illustration of the "law of specific sensations" that by whatever means the auditory nerve may be stimulated, the result is sensations of sound.

The amazing and unexplained possibilities of the finest sense of hearing

Disturbances in the circulation in any part of the middle or inner ear, spasm of the tensor tympani or stapedius muscles, and other local causes are thus able to excite the auditory nerve, and the result is sound-sensation, just as pain follows any excitation of its specific nerves, and vision follows any excitation of the optic nerves.

Vastly complicated as the cochlea is, it affords us little clue to the astonishing possibilities of the sense of hearing, as they are exhibited by the trained musician. The ear of a good violinist can distinguish fifty distinct notes or levels of pitch between F and G in the middle of the piano. The range of the eye for light extends to rather less than one octave — *i.e.*, roughly, from about 400 to about 750 millions of millions of ether-waves in a second. The ear has a much wider range, extending considerably beyond the seven octaves of an ordinary piano in both directions. The lowest notes perceptible by the ear consist of about twelve to sixteen vibrations per second, and the highest, like the bat's squeak, run up to thirty-five or forty thousand. People of trained musical ear can distinguish more than twelve thousand separate notes or qualities of sensation between these two extremes.

Ever since the time of Helmholtz one theory has followed another in the attempt to explain how these thousands of different sensation-qualities are distinguished. There is much to be said for the piano or resonance theory, in one form or another, but much also to be said against it. Sound-waves are too large to answer at all well to the requirements of anything so tiny as the organ of Corti. Helmholtz was assured that, by some material mechanism of the many with which it is provided, it analyzes complex vibrations, such as nearly all sounds are made of, especially musical sounds, and so sends to the brain separate and distinct impulses to correspond to each part of, say, a musical chord.

The brain reached physically, but ineffectively, by direct sound

But it is impossible to maintain that the cochlea is capable of analyzing complex vibrations. All we can credit it with is extreme acuteness of perception, and the power of sending nerve-impulses which reach the brain *en masse*, so to say, and are dealt with by it. The nineteenth century did its best to furnish a mechanical explanation, but the laws of mechanics forbid any such explanation to suffice for the case of the cochlea. We must go back to the brain, where mechanics and every other department of physical science break down. There can be no doubt that it was not physically correct to say that sound stops at the cochlea, as light stops at the retina. In point of fact sound-vibrations must go right through the head, including the brain and the auditory center. This is the one case where a sensory stimulus actually strikes the sensory center.

The brain aroused only through the appointed mechanism of the ear

Vision, touch, smell, taste — all these are excluded from direct action on the brain, and the stimulus must do all it can at some remote nerve terminal. But sound-waves are not so excluded, and actually traverse the auditory center itself.

We might very reasonably suppose that the whole aural apparatus is therefore more or less of a superfluity, and that our ex-

planations of hearing should try to deal with the direct action of sound-waves upon the brain. But pathology quickly tells us that hearing is made impossible if the auditory apparatus breaks down in any way, and that the problem here is therefore the same, after all, as that of the other senses. If the auditory nerves be thrown out of action, the centers are found to be quite unaffected by the sound-waves which must pass through them. And the fact is not without a parallel, for it is known that the cerebral centers for touch-sensation are entirely insensitive when they themselves are touched. Only through the appointed nerves can any of these cerebral centers be aroused. It is therefore practically, though not physically, correct to say that sound stops at the cochlea as light does at the retina.

Fine appreciation of sound more remarkable than a sense of absolute pitch

We are thrown back on the auditory center and its properties if we desire to learn how the ear analyzes and identifies sounds. Anatomists may call the cochlea the "inner ear", but the real "inward ear", like the "inward eye", is to be found in the *cortex cerebri* alone. We have already observed the range of its capacities, but their quality has scarcely been suggested. Many musical people have what is called "absolute pitch", which means that they can identify the pitch of any musical note they hear. The brain can carry its memory of pitch so that the hearer can say, at once, and without calculation or thought, that the motor-horn in the street sounds A, or that a whistle is in F sharp, and so on.

But the study of acoustics shows that the ordinary qualities of ordinary ears are really more remarkable than this sense of absolute pitch. When we distinguish the same note sounded by a horn, an organ, a piano, a violin, a clarinet, a friend's voice and a second friend's voice, our ears prove themselves capable of distinguishing and identifying the minute "overtones", or "harmonics", which constitute the difference between these different sounds, all of which are of the same fundamental pitch.

Orchestral and choral conductors possess fineness of aural discrimination which is almost incredible, readily picking out a wrong note played by one of perhaps a hundred and twenty instrumentalists. Yet acoustics tell us that separate sound-waves from each instrument cannot possibly reach the ear when we hear an orchestral chord. When more notes than one are sounded simultaneously, the resulting wave-form is a complex product, which is none of its constituents, and yet is affected by each of them. But the ear is capable, so to speak, of reconstructing in its entirety the sound-wave which does not really exist at all as such, but only as a modifying factor in the complex blended wave which reaches the ear. It will be evident that, since a particle of air cannot be simultaneously moving in two different directions, what happens when two different waves travel through the same air is that neither wave can survive as such. They destroy each other, and produce something else. But from the features of that something else the musician's ear can readily reconstruct and imagine that it hears each or any of the waves which were destroyed in order to produce it. What, then, can we positively assert of the cortical center? For instance, must we begin by assuming that there is a separate process, a separate substance, or a separate cell, for each of the twelve thousand distinct aural sensations which a good ear can identify?

The appreciation of gradations of sound similar to that of gradations of color

The answer to this must be negative. There cannot be so many distinct processes, but there must be a much smaller number of distinct processes which blend with one another in varying proportions so as to produce all the different pure tones, twelve thousand or so in number, which a good ear can identify.

This is rendered the more probable by the very definite evidence of vision, when we saw that the infinite gradations of color which the eye can distinguish are dependent not upon a separate provision, somewhere, for every possible tint, but upon

the varying proportions in which a very few primary sensations are excited. Most students believe four will account for all the possibilities of color-vision, and no theory demands more than six. In the case of the ear the number must be larger, though probably not more than fifty. This, however, is a very small number compared with twelve thousand, and it seems necessary to believe that every note we can hear depends upon a blending of these primary pitch-sensations, each of which, perhaps, corresponds to some definite substance in the auditory center.

Musical discrimination dependent on the proportions of a few primary elements

Perhaps the best of the evidence which suggests that our musical discrimination depends upon so few primary elements is that:

"If each distinguishable tone were an elementary quality, we should expect that when the air is made to vibrate at a steadily increasing rate, as when a violinist runs his finger up the bowed string, or the length of a whistle-pipe is regularly diminished while its note is sounded, the pitch would rise by a series of steps from one elementary quality to another; but this is not the case, the transition is perfectly smooth and continuous. A concrete example will make this point clearer: If two elementary qualities are excited by 196 and 200 vibrations per second respectively and are just perceptibly different in pitch, then the tone excited by 198 vibrations per second should be identical in quality with either 196 or 200, it should be of one or other of these elementary qualities. But we know that it is identical with neither, for it is distinguishable from 194, from which 196 is not distinguishable, and it is distinguishable from 202, from which 200 is not distinguishable. The rise in pitch seems, in fact, to be perfectly continuous and the differences of pitch infinite in number; such continuous variation of quality indicates that, as in the case of the continuous changes of quality of the color-scale, the change is due to a continuous change in the proportion of two or more constituents of a complex."

The lack of satisfactory studies of the brains of the musical and non-musical

Thus the musician will see that the continuity of his sense of pitch, and his capacity to appreciate pitch at any level, and to hear perfectly no matter to what exact pitch his instruments are tuned, depend upon the fashion in which pitch is appreciated — by the proportions in which certain elementary pitch-sensations are blended. But so far it is impossible to say what are the "primary pitches", corresponding to the "primary colors" in color-vision.

Microscopic study of the auditory center in the temporal lobe of the *cortex cerebri* has hitherto shown very little. This area of cortex, which has such a distinctive function, is not markedly differentiated in cell-structure from the areas which surround it. For instance, we find no marked local peculiarities like the large pyramidal cells of the psycho-motor area. All we can say is that the extent of this area is large in man. There is no evidence as yet to show that its microscopic structure is peculiar in tone-deaf persons, who correspond to color-blind persons fairly closely, nor have we at the present time any comparative study of the cortex in non-musical and musical persons, and in very great musicians.

It will be for future ages to make these inquiries when a different state of public opinion enables students to have access to different types of brains, when their former owners have no further use for them. It can be asserted positively, however, that nowhere is inheritance of psychical characters more evident than in this realm, and further psychological analysis of the musical sense will probably enable us to assign Mendelian ratios to the inheritance of certain of its constituents.

The functions of the mechanism of the ear only those of a messenger

We saw that the functions of the retina, though that is historically a part of the brain, are very humble compared with those of the visual cortex, as it is often called for short. Just so is it with the auditory cortex and the organ of Corti.

The receptive organ plays no part in memory, perception or any creative process. It simply receives impressions, and sends nerve impulses accordingly. All the rest is done by the cortex. All memories of sounds are stored there; it is the seat of "absolute pitch" in those who possess it; and the unknown physical agents by which we distinguish pitch at all must have their seat there. It is the auditory cortex that is at work in dreams of hearing and in all forms of auditory hallucinations and delusions (as distinguished from singing in the ears and similar disturbances). When we "hear voices" inspiring us to do deeds like a Joan of Arc, or to write noble words, it is the auditory cortex, the real inward ear, that is involved, whatever the whole explanation of these facts may be.

The true *status* of the auditory cortex in relation to musical conception and creation is furnished by the celebrated instance of one of the greatest musicians that ever lived, Ludwig von Beethoven.

The auditory cortex of the brain the sole seat of musical memory

Of course, there are no grounds for the popular view that musicians compose at the piano. They may improvise or "play about" there, but the musician composes at his desk, just as an author writes. His auditory apparatus is not concerned in the least, but his auditory cortex is indispensable. In destruction of the auditory cortex all possibility of musical appreciation, let alone creation, vanishes.

Beethoven was early attacked with slight deafness, which gradually increased until, for many of his latter years, he was stone-deaf. It may be asked whether we can now say if this deafness was of central origin, in the cortex of the composer, or had its cause somewhere in the aural apparatus; and that question can be answered at any time, without the aid of any examination, from the simple fact that during those years of absolute deafness Beethoven was composing some of the noblest and most beautiful musical compositions in the whole literature of the art. Assuredly his auditory cortex was intact, and by means of it he was enabled to conceive and create melodies, harmonies and combinations of tone-color which he never heard at all, even though he sometimes conducted performances of them, and yet which, in some sense no less true, he must have heard incomparably.

It is to be observed, then, that the auditory cortex is not merely capable of recalling sounds or melodies, as when we think of a tune, and, so to speak, hum it mentally, but it is also capable of conceiving sounds and sound combinations which it has never heard and never can hear.

People who think by sight and people who think by sound

Recent researches have shown that the great majority of people can be classified in one or other of two psychological types, corresponding to the two great senses described in this and the preceding chapter. These classes sometimes are called the "visuals" and the "auditives" respectively. The "visuals" or visualizers seem to conduct the majority of their mental processes by visual symbolism. They "think in pictures"; their mental method is graphic. The majority of women belong to this group, and, of course, the majority of painters, sculptors, architects, decorators, engineers and mechanically gifted people. Such people readily apprehend space-relations, and can conceive new ones. If they possess this power in high degree, they may paint fine pictures, build new types of architecture, conceive new machines.

The auditives, on the other hand, think more in sounds and words, and not in pictures. They naturally include the musicians, the men of letters and the scientific and philosophic people. They are more numerous among men than among women. They notice things around them less, and are more commonly credited with being "absent-minded." If great development of either is rare, vastly rarer is great development of both in one and the same individual. Such individuals stand out as the few supreme examples of what we call versatility, and of these the most notable representative in the history of the world was Leonardo da Vinci.

THE EFFECTS OF ALCOHOL

An Outline of the Evidence that Alcohol Does Not Keep out, but Lets in, the Body's Enemies

THE STORY OF AN UNHOLY ALLIANCE

WE must now try to compress within a reasonably brief compass the results of the many investigations that have been made by exact methods into the actions of alcohol upon the body in health and disease. These investigations have resulted in a formidable body of knowledge, only the main outlines of which can here be presented.

Like chloroform, ether and a large number of allied substances, alcohol must be numbered among what are called the "protoplasmic poisons", the action of which is essentially toxic to all forms of protoplasm, or living matter. Even the yeast-plant is soon killed by the alcohol it produces, if that be allowed to accumulate. The action of alcohol upon green plants also can be definitely classed as toxic; and when we pass to the animal world, the results are the same. Alcohol acts as an antiseptic, by its action upon the microbes of putrefaction, and it thus ranks high as a preservative of all forms of corpses; but for the living body, upon whose cells it acts as upon the living cells we call microbes, its preservative action is naturally reversed. If we begin with the simplest animal cell, such as the amœba, this destructive action of alcohol, beginning with paralysis (perhaps after a brief stage of what simulates stimulation), is clearly shown. From this humblest we may pass to the highest form of animal life — that of our own bodies; and this extreme transition will be justified when we remember the astonishing resemblance between the free-swimming white cells of our own blood and the amœbæ of the ponds. In general, the reactions of these types of cell are notably similar, and it is so here.

The consequences are of the gravest. As we saw at the very beginning of our present study of health, the leucocytes, or white blood cells, are an important factor in defending the body against invasion by disease germs. In the presence of such foes as, say, the microbes of pneumonia or consumption, the number of leucocytes in the body increases; and, given the invasion, this multiplication of the leucocytes, which is known as leucocytosis, is a good omen for the patient, for though we call it a "symptom" of the disease it is really a demonstration of health, and the best promise for its return. Many years ago Professor Metchnikoff found, first by study of a minute creature called the water-flea, that these leucocytes attack and destroy microbes and other invaders of the body. Later he proved, at the Pasteur Institute — and his results have been repeatedly confirmed and amplified since — that alcohol, present in the blood even in surprisingly small quantities, paralyzes the leucocytes, so that they cannot do their work so well.

After giving an account of his long series of studies, Prof. Metchnikoff stated that "as a logical consequence of the experiments on the weakening of immunity under the influence of alcohol, it has been suggested that we must eschew this substance in the treatment of infectious diseases. . . . We must strongly insist on the danger of alcoholism with regard to resistance against disease-producing microbes."

Other investigations have added to Metchnikoff's study of the white corpuscles evidence of the share which other elements of the blood take in normal resistance to disease.

How the blood fights disease

Thus the plasma of the blood is able to produce chemical substances that deaden or kill the germs and is therefore called "bactericidal". This is supposed to aid the white corpuscles in devouring the bacteria. The blood also produces substances that oppose the germs or counteract the poisons they produce. These are called "antibodies" and "antitoxins". Diphtheria antitoxin is an example.

The red corpuscles also play an important part in defense in disease attacks as well as in health. Their efficiency depends upon their power to retain the pigment, hæmoglobin, upon which their absorption of oxygen in the lungs depends. When the chemical composition of these corpuscles is changed from normal, either by lack of proper nutriment or by poisons circulating in the blood, their power to hold this essential pigment is weakened and the body suffers from lack of nitrogen.

The evidence that alcohol lessens the power of resistance against disease

The effect of alcohol upon each of these factors in disease resistance has been investigated, and the trend of all the reports is that alcohol impairs one or more of these processes. As the Journal of the American Medical Association conservatively puts it, in substance, after reporting recent experimental evidence of the weakening effect of alcohol upon resistance: "Although the extent and constancy of the damage cannot yet be stated with mathematical precision, there is sufficient agreement between the latest researches and what preceded them to throw the burden of proof upon those who would defend the regular use of alcohol."

Artificially induced immunity against special diseases, such as typhoid fever, cholera and tetanus has recently been added to the list in which innoculation against smallpox was the pioneer and that against rabies the product of Louis Pasteur's genius. Reports from specialists in all these lines testify that greater difficulty, or even failure, is frequently encountered when they try to induce immunity in alcoholic subjects.

Concerning hydrophobia, Prof. Metchnikoff said the vaccinations against hydrophobia carried out on persons bitten by mad animals are almost always successful, but those cases in which the treatment does not stop the outbreak of the disease are most frequently observed in individuals addicted to alcohol.

A great decline in the use of alcohol as medicine

This knowledge of the unfavorable action of alcohol upon the body's powers of disease resistance has contributed to the marked decline in the use of alcohol in pneumonia, typhoid fever and other diseases in which it used to be given as a regular routine. Where hospitals formerly spent dollars for alcohol they now scarcely spend cents. During the years 1897 to 1906 the expenditure for alcoholic liquors in the Massachusetts General Hospital fell off 71 per cent (Cabot, 1909). The fact that whisky and brandy were dropped from the United States Pharmacopœia, the standard for the principal drugs used for medicinal purposes in the United States at its last revision (1915) is further evidence of the declining place occupied by alcohol as a medicine in the opinion of those specialists who are best qualified to judge.

But while the alcohol bill in hospitals has fallen with a rush, the milk bill has steadily risen, and results steadily improve, both as regards the death-rate and the length of convalescence. This applies not merely to such "medical" diseases as pneumonia, but also to "surgical" diseases. As we have seen, in both alike the essential fact is the same — the fight between the body, and its defenders, on the one hand, and invading parasites on the other.

The proof from pneumonia statistics that alcohol is detrimental

In a scientific work it is necessary to appeal to evidence, and here we may briefly mention hospital experiments which have led the foremost members of the medical profession to adopt their present practice. In one instance, pneumonia patients or their relatives were given their choice as to whether they should have alcohol or not.

Every condition was made identical, in the two sets of patients thus chosen, except on this one score. Over a long period, and with a large number of cases, it was found that the death-rate was about 15 per cent higher in the patients who were treated with alcohol than in those who got none. Interesting questions of responsibility clearly arise when we come to appraise the usefulness of practitioners who still adhere to nineteenth century practice in this respect.

Former arguments for medical use of alcohol based on false supposition

One of the diseases in which the use of alcohol was thought to be necessary, and for which it was upheld by such prominent teachers of medicine as Sir Thomas Fraser of England, was fever. The argument, as taught by the English professor, who later definitely and unreservedly abandoned it in his practice, was that the body requires food in fever; that the process of digestion is difficult or even impossible in this condition of the blood, and that therefore we should give alcohol, which was believed to be a food, with the special virtue that it requires no digestion whatever, but can be absorbed as it is into the blood and from the blood by the tissues. So long as the major assumption was granted, this seemed sound argument; but, as we have seen, in the great hospitals, alcohol has nevertheless been abandoned and replaced by milk (which can easily be predigested outside the body), even in fever.

The reason for the change in practice is that the supposed food-value of alcohol has not been upheld by subsequent research. The drug is in part destroyed, but that, as we have seen, proves nothing. Careful experiment upon the heart, the condition of which is so important in all acute fevers, has shown that alcohol does *not* support its action, though sugar does. In fact, nothing is more notable in recent chemical physiology than the steadily increasing evidence in favor of sugar before decomposition, and against the characteristic product of that decomposition. As we already know enough to see, every food substance must either supply a necessary ingredient of the bodily composition, or it must be a source of energy, or it must somehow expedite necessary bodily processes. As regards the first of these possibilities, no one claims anything for alcohol. It may be found in minute traces in the abstainer's body, but only as an effete product. Nothing alive, other than the vinegar bacillus, tries to live upon it, except man. It does not occur in milk, except in that of the drinking human mother. It contains no nitrogen, and is thus incapable of forming a part of any living tissue. But, though it thus has no claims to rank with the proteins, it might supply energy, and thus be what is called a "protein-sparer", preventing the body from having actually to burn its proteins, in the absence of any cheaper fuel — as a householder might have to burn his piano and floors in the absence of coal and wood. But the evidence now available strongly suggests that alcohol cannot rank as a food of this class, for it does not reinforce the energies of muscular tissue, as the experimental study of alcohol and other substances perfused through isolated and surviving hearts, removed from animals first killed, has shown.

Alcohol not a source of energy because it lowers the temperature

Most notably, the claims of alcohol as a source of energy, whether muscular energy or heat energy, have to face the fact that this substance lowers the temperature of the body, instead of raising it. The so-called "protein-sparing" action of the drug has its logical explanation in its interference with the nutritive processes which involve the use of the protein and the fuel-foods. It is a general property of alcohol that it retards fermentation. This is doubtless the key to its action on living matter, since life, physically considered, is a series of fermentations. Now, the processes by which the body utilizes its food are all fermentative, and alcohol interferes with them at their very beginning by its action on those initial processes of fermentation by which the red cells of the blood give up to the tissues the oxygen they have gained from the lungs.

The direct interference by alcohol with the internal process of combustion

This action of alcohol upon the red cells of the blood is probably only one degree less important than its action on the white cells. The business of the hæmoglobin which gives the red cells their color is to form a loose compound with the oxygen it meets in the lungs, and this compound, known as oxy-hæmoglobin, is decomposed by ferment action wherever the tissues need it. But alcohol, like certain other substances, has the property of interfering with this sequence of events, so that the oxy-hæmoglobin is not readily decomposed, and thus the tissues are "starved in the midst of plenty" of oxygen. Hence one reason why alcohol lowers the temperature of the body — by its direct interference with the combustion whence the body derives its heat. Hence also we find that the habitual consumption of much alcohol, in cases where the stomach of the drinker is resistant and alcoholic dyspepsia does not supervene, usually leads to the accumulation of superfluous, unoxidized tissue in the body, and the drinker becomes obese. Certain alcoholic beverages, such as beer, contain small but definite amounts of food material which, if properly burnt up, would provide the body with heat and energy, but the alcohol which is taken with them interferes with their combustion, and consequently leads to the storing-up of unused material.

The new view of the action of fever on the body

The diminished production of heat may be of still further importance. We know definitely that the maintenance of the normal temperature of the body enables it to resist the attacks of microbes. We know also that when microbes have taken their hold upon the body it commonly raises its own temperature — with the production of what we call fever — for the purpose of aiding it in its resistance. Until recent times doctors have regarded fever as vicious in itself, and have opposed it by all manner of means, especially irrational ones, such as antifebrin, antipyrin and other drugs which lowered the temperature by a directly poisonous action upon the vital efforts which were raising it. We know now that such methods were disastrous. Furthermore, it has been proved by crucial experiment and observation that the various degenerative changes in the body, which used to be ascribed to fever, are not at all the results of the raised temperature of the body, but are toxic, the results of its poisoning.

Fever a part of the bodily reaction against poisons

If the poisoning be present, but the temperature kept down, these disastrous changes still occur. If the temperature be artificially raised, as in a Turkish bath, or internally raised in hysteria, in the absence of microbic poisoning, and be maintained for long periods even at levels which sound incredible, these degenerations do not occur. And we are now certain that fever is part of the bodily reaction against poisons, and is valuable on many accounts — as, for instance, that poisons will be more quickly burnt up in a hotter body.

It follows that a second argument for alcohol in fever, which was maintained as lately as twenty years ago by distinguished authorities, must be abandoned. They argued that alcohol was useful in lowering the temperature of fever. But now we see that any substance which tends to interfere with the normal production of the bodily heat tends, therefore, to lessen its powers of resistance to microbes. Thus we find that the action of alcohol upon the red cells of the blood has, in effect, the same result as its action upon the white cells, which we have already studied. Not only does it directly paralyze the defenders, but it interferes with the conditions under which alone, if they be not paralyzed, they can best do their work.

Further, it is notorious that alcohol dilates the superficial blood-vessels of the body — not merely those of the face only, but those of the body as a whole. By thus throwing a large amount of blood to the surface, which is in contact with the cool external world, it markedly increases the loss of heat from the body.

It thus strikes at the maintenance of the bodily temperature in two complementary ways: by interference with the production, and by acceleration of the loss of heat.

The effect of taking a dose of alcohol on a cold winter's night

A dose of alcohol on a cold night, when one leaves a warm room, thus makes one feel warm, which we call keeping out the cold, but which is really letting out the heat. The nerves of temperature, which are situated in the skin, cannot distinguish between these two opposites, but the body pays its price. We fancy that if we feel warm we *are* warm, but our judgments are superficial, as are all judgments based on mere sensation without reflection. If the terminals of the nerves of temperature be bathed in a large quantity of rapidly flowing blood, for a time we feel warm, and the warmer the more rapidly we cool. We thus have a complete explanation of the fact that the absorption of alcohol, with subsequent exposure to cold, so frequently results in pneumonia, which is still by far the most fatal of all acute diseases. The microbe of pneumonia is quite commonly found in the mouths of healthy persons, waiting for a breach in the defenses, a bout of intoxication on the part of the white garrison, or some other opportunity. The ingenuous amateur marches out into the night, fortified by a dose of whisky in order to keep out the cold. His idea of keeping out the cold is to give out as much heat as possible to the cold, and to interfere, as far as may be, with the production of any more heat; and in order to do the thing up brown he arranges for the paralysis of his leucocytes. It would be a poor sort of *pneumococcus* that did not take advantage of such a chance.

The significance under different circumstances of a decline in temperature

We know that there are drugs — lamentably few — which lower a high temperature by striking at the cause which has incited the body to produce more heat. Quinine in malaria is such a drug. It kills the parasites that make the fever necessary, and with their death it declines.

But to interfere with fever, while doing nothing to interfere with the activity of the microbes which have evoked it, is more akin to manslaughter than to medicine. Hence, the doctor of today who is abreast with the leaders of medical science, welcomes the decline of his patient's fever if he believes that this indicates the disappearance of the need for the fever; but as long as the need persists — a need which alcohol does nothing to remove — he desires to see the fever well maintained, and nothing alarms him more than the failure of the body to maintain it in such circumstances. He knows that the falling line of the temperature chart may mean either the destruction of the invaders or the failure of the defenses; and he will no longer be deceived into paralyzing the defenses with alcohol under the delusion that the decline in temperature thus caused indicates the destruction of the invaders.

The diminution of the white cells of the blood in alcohol consumers

The relations between alcohol and the fluid part of the blood are still, as a whole, quite unknown; but, indeed, physiology cannot yet pretend to have any more than a superficial knowledge of the chemistry of the blood, in which lie many great secrets still unlocked. But one important fact in regard to the white cells needs to be added. It is that, in those who regularly take considerable quantities of alcohol, the number of white cells in the blood is markedly diminished. We do not yet know how the chronic consumption of alcohol has this result, whether by increasing the death-rate of the leucocytes or by lowering their birth-rate in the blood-cell-forming tissues, such as the spleen, but our knowledge of the physiological effects of alcohol would suggest that it acts in both of these ways. This remarkable discovery leads us to expect that the mortality from microbic diseases in general, among the alcoholic part of any population, including even the regular moderate drinkers, will be definitely and constantly higher than among those who do not take alcohol. And this, indeed, is the established fact, confirming Metchnikoff's teaching.

The comparative immunity of the abstainer from illness

Other statistical evidence is abundant, and constantly increasing — uniformly in the same direction. Insurance records in the United States and elsewhere have clearly shown that the abstainer enjoys so high a degree of relative immunity from microbic diseases in especial that he lives, on the average, for several years longer than his fellows. The theory that this is, however, a pallid and worthless existence need only be countered by the further actuarial demonstration that, during his longer life, he suffers annually on the average, from several days' less illness.

In a careful investigation made of the records of forty-three life insurance companies in the United States and Canada, the policy-holders were divided into several classes. Those with a past history of heavy drinking who had reformed without treatment, showed a mortality rate 32 per cent higher than that of the general class. Those who took the equivalent of two glasses of bear or one glass of whisky a day, showed a mortality excess over that of the average policy-holder of 18 per cent. Former heavy drinkers who had not drunk heavily for five years before being insured had a death-rate of 40 per cent above the average. Those whose daily amount was four to six glasses of beer or two glasses of whisky prior to application, but who were accepted as insurance risks had a mortality 86 per cent in excess.

"This means," say Dr. Eugene L. Fisk and Professor Irving Fisher in "How to Live", "that steady drinkers who exceed two glasses of beer or one glass of whisky daily, are not, on the evidence, entitled to standard insurance, but should be charged heavy extra premium."

Alcohol not protective against consumption

Tuberculosis, the commonest and most deadly of all diseases, involves questions too large for discussion in this section, which deals only with personal hygiene; but the influence of alcohol upon the individual, in his personal relation to the tubercle bacillus, certainly concerns us here.

The better knowledge of alcohol has changed the idea formerly held that it was antagonistic to tuberculosis. It is now looked upon as one of the great predisposing factors in the production of both acute and chronic pulmonary tuberculosis; and it is generally accepted that in alcoholic patients tuberculosis is far more likely to assume an acute and generalized form than it is in the non-alcoholic patients; for, as Dr. Dickinson said: "We may conclude, and that confidently, that alcohol promotes tubercle, not because it begets the bacilli, but because it impairs the tissues and makes them ready to yield to the attacks of the parasites."

In France a few years ago the districts consuming the most alcohol were found to have the highest mortality from tuberculosis, alcohol apparently acting as a devitalizing agent, and rendering the person addicted to it a more easy prey to infection.

A few years ago the Phipps Institute, Philadelphia, for the treatment of tuberculosis, published statistics covering a period of two years showing the difference in response to treatment between non-alcoholics and alcoholics, defined as "those who had used enough alcohol to do themselves some physical harm". The improvement was from 30 to 50 per cent greater in the non-alcoholics than in the alcoholics. The mortality in the two years averaged nearly 140 per cent higher in the alcoholics than in the non-alcoholics. The mortality among those having alcoholism in the preceding generation was 80 per cent higher than in those who had no such family history.

It is now known that pure air and good food are the all-important requirements in the battle for recovery from tuberculosis. Alcoholic liquors are liable to disorder the digestion, upon which so much depends. Pure air with rest, and occasionally a little exercise, as much as can be borne without fatigue, are the best stimulants to appetite.

Dr. S. A. Knopf, the New York specialist on tuberculosis, says: "Alcohol has never, and never will, cure tuberculosis. It will either prevent or retard recovery."

Resolution of the International Congress on tuberculosis in regard to alcoholism

These conclusions have been extended and confirmed in later years. The International Congress on Tuberculosis, when it met in Paris, passed a unanimous resolution to the effect that the fight against tuberculosis must everywhere be combined with the fight against alcoholism. At a later meeting in Rome, a great quantity of additional evidence was forthcoming, not least from unfortunate Italy, where the rise of industrialism and the concentration in cities have given great opportunities to the allied forces of alcoholism and tuberculosis.

The liability to cancer definitely increased by taking alcohol

A very remarkable indication of the subtle action of alcohol upon the chemistry of the body has been furnished from the study of cancer. This terrible and still imperfectly understood disease essentially consists of the development of "cannibal cells" from and in the cells of the body, in which an internecine and usually fatal war is then waged. Though these rebel cells act in all cardinal respects like parasites, cancer is almost certainly *not* due to a microbe or parasite of external origin at all. The relations of alcohol to this disease might therefore very well be wholly different from those which obtain in the case of the vast majority of all forms of disease. But careful study has shown that, other things being equal, the liability to the development of cancer is definitely increased by the consumption of alcohol.

The greater frequency of cancer of the alimentary canal in men engaged in occupations that encourage alcoholic indulgence is one indication of an influence exerted by alcohol. At first sight this appears to mean that the customary presence of alcohol in the tissues — and we know that the regular drinker is constantly under its action, for a single dose is operative for more than thirty hours — leads to the change of type which occurs when normal cells become cancerous.

Self-cured cancer and consumption more frequent than we realize

The present writer is strongly of opinion that that is not the true explanation, for many difficulties stand in the way of its acceptance — notably its failure to explain the *local* character of the disease. But, as modern students of cancer are now demonstrating, that disease occurs, like consumption, far more frequently than we used to suppose, and probably by far the greater number of cases undergo a natural cure. The local development is due to local causes, acting how we cannot yet say, and then the question is whether the rest of the body will resist successfully or not. If it be successful, nothing more is heard — probably nothing was ever heard — of the disease. We know no more of it than most of us do of the fact that we carry healed tubercle in our lungs and elsewhere. The silent forces of the bodily resistance have simply done their work; and there is some reason to suppose that in cancer, as in other cases, the leucocytes do great service on behalf of the body.

However that may be, the teaching of today is that the body's resistance is what, above all, matters, not in one disease, or two or twenty, but in *all*. Microbes and parasites of all sorts attack us, and the question is whether we can resist them. Our own cells turn parasitic, and the question is the same. We unknowingly take non-microbic poisons, such as lead, if we work with that metal, and the question is the same.

In all of these types of cases, which cover between them practically all the ills that flesh is heir to, alcohol has been proved to lower resistance. The white blood-cells may or may not be concerned, but always some cells or other are concerned, and the essential action of alcohol on all living cells, animal or vegetable, is the same. We have seen how it affects cells of relatively low type, like the leucocytes. In the next chapter we shall see how it affects the cells and functions of the brain; and elsewhere — for the subject is not part of personal hygiene — we shall see how it affects the germ-cells.

ONLY MOVIE MUNICIPALITY IN THE WORLD

BIRD'S-EYE VIEW OF UNIVERSAL CITY

MAIN ENTRANCE TO UNIVERSAL CITY

THINGS SEEN AS THEY ARE

An Invisible World of Movement Revealed in One Ten-Millionth of a Second by an Electric Spark

REVELATIONS OF THE CINEMATOGRAPH

AT first glance it seems inexplicable that the actual movements of life can be reproduced by passing a series of pictures on a transparent material before a lantern at the speed of about sixteen a second. But, as a matter of fact, every conjurer has a practical knowledge of the principle involved in the most popular of modern scientific inventions. The old saying about the quickness of the hand deceiving the eye is the explanation of the marvels of cinematography.

Men of science merely put it in other words when they say that the moving picture is an illusion produced by "persistence of vision." The human eye is extraordinarily defective, and the eye of the civilized man is blinder than that of the savage. It takes about $\frac{1}{24}$th of a second for the ordinary human eye to get rid of a single image formed on its retina. During that $\frac{1}{24}$th of a second, it is possible to create in succession at a single point nearly half a million electric sparks. The eye, however, cannot see even two of these sparks. All that it gets is one impression of a steady, unbroken light. That is to say, it is utterly blind to 499,999 things taking place within a few feet of it. The image of the first spark persists on the retina, and prevents the eye from seeing any of the successive flashes.

This is the defect of persistence of vision. It will easily be understood by regarding the eye as a photographic camera which is attached by a kind of telegraph wire to the brain. When the lens of an eye is adjusted to an object, the rays of light form an image on the retina — which is a dark screen at the back of the eye.

Behind the retina runs the optic nerve, along which the image is transmitted by, so to speak, a kind of telegraphic code of nervous impulses to the brain. The brain does not have a picture thrown on it. All that it receives is a set of nervous sensations, out of which it reconstructs a conception of the actual image printed on the retina. The brain is somewhat slow in its work of reconstruction; and, having at last formed its own picture, it will retain that picture for some time after the real object has disappeared from sight. In the meantime, a multitude of other objects may flash into view, but they pass unnoticed. "The line is busy."

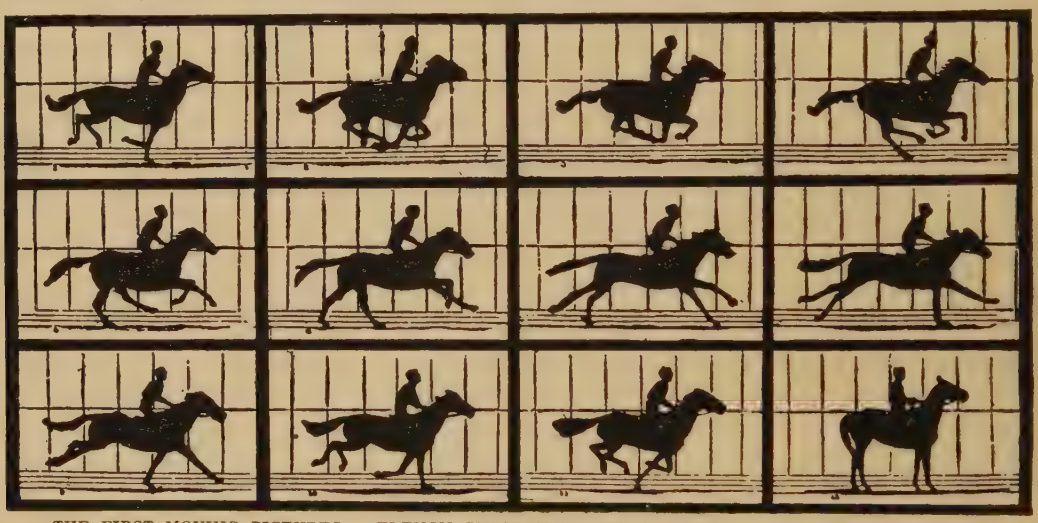
Thus we see only a very small part of even large movements which are continually going on a few yards away from us. We cannot perceive, for instance, what motions a horse makes as he gallops past us only a few inches from the curb on which we are standing. We cannot see the various attitudes a man takes when he is running. All our pictures of movement are lamentably conventional.

When the famous French artist Meissonier was at the height of his powers, he became the laughing-stock of France. Years of loving study of the action of horses had so trained his eye that he saw movements of their legs invisible to other men. Unfortunately, in painting some pictures of cavalry charges, he used his new knowledge; and both the public and the art critics began to lament the fact that the most wonderful of modern draftsmen seemed suddenly to have lost his genius, and taken to drawing horses in a way that any child could see was wrong.

It was in 1872 that Meissonier's reputation was apparently ruined, but in that year Eadweard Muybridge created the new science of the study of living movements. He placed 24 cameras side by side along an exercising track at the Palo Alto Stud Farm. Across the track twenty-four threads were stretched, and each connected with a powerful spring controlling the shutter of one of the cameras. A horse was then ridden along the track, and, as it passed each camera, it broke the thread and released the shutter, thus photographing itself in its progress. Very curious were the attitudes revealed. Meissonier heard of the experiments, and invited Muybridge to give an exhibition in Paris of the remarkable pictures. The exhibition vindicated the artist. The very things for which he had been condemned became evidence of the fact that he was the quickest-eyed painter of modern times.

But a more important result of the exhibition of Muybridge's studies of movement was the impetus that it gave to the science of the moving picture, which is now one of the most popular means of amusement, and one of the most promising instruments of scientific research. His achievement drew the attention of the civilized world to the facts of persistence of vision, and by revealing to the human eye this defect led directly to the art of cinematography.

Wonderful as is the cinematograph, it is difficult to name its inventor. The fact is that a considerable number of men in the United States, France, Germany and England, were simultaneously engaged in working out the problem of animated photography, and success was achieved by their joint work. In the early part of the nineteenth century, Sir John Herschel and a friend made a very simple toy in which the main principle of cinematography was used. On one side of a small round piece of cardboard was painted a bird, and upon the other side was painted a birdcage. The card was suspended between two pieces of sewing silk, held between the forefinger and thumb of each hand. When the card was revolved rapidly by means of the threads, there was produced a combined picture of a bird inside a cage. Such seems to have been the first application of the principle of persistence of vision; and when studied in connection with Muybridge's work it was further developed into the animated pictures which M. Reynaud displayed in Paris in 1877.



THE FIRST MOVING PICTURES — ELEVEN SUCCESSIVE PHOTOGRAPHS OF A GALLOPING HORSE

Reynaud's picture-palace excited great interest when it was opened. On a large white screen in the front of the stage were shown scenes of life just as striking as those now displayed in the modern way. The principal difference was that the Frenchman used painted pictures instead of actual photographs.

Figures in successive stages of movement were carefully painted at regular intervals on a long band of transparent material which, when passed quickly through a lime-light lantern, projected the images in rapid succession on the screen. The machine was more complicated than that now used, because Reynaud employed two lanterns and two sets of pictures. He first threw on the screen a motionless picture of a room or street. This formed the setting for the animated images, somewhat as the scenery of a play serves to frame the action. Only the figures were painted on the moving transparent band, but when they were projected on the screen they combined with the set scenery. This saved the cost of painting the scene, as well as the figures, on each of the moving pictures.

TWO DRAWINGS SHOWING THE PRINCIPLE OF THE CINEMATOGRAPH

In these drawings a single action is split into seven parts, which, passed quickly before the eye looking at them through a slot, would give the impression of a single movement.

The cost of painting the long band of moving figures was very great. It was, in fact, this which prevented the picture-palace from becoming a cheap and popular place of entertainment fifty years ago.

Naturally, many inventors saw that photographs could be used instead of painted pictures. Various kinds of apparatus were devised for taking photographs at the rate of sixteen a second, and moving them at the same speed before the eyes of the spectators. Excellent results were sometimes attained, especially by Marey and Demeny, of Paris. Dr. Marey had a camera which could take photographs in $\frac{1}{2000}$th part of a second; and his fellow-worker, M. Georges Demeny, was ready with an ingenious apparatus which projected moving pictures on the screen. Only the slow and cumbersome glass plate then used in photography prevented the two Frenchmen, who are generally considered the fathers of cinematography, from popularizing their discoveries.

What was needed was a transparent photographic film, which could be made in a long band, like the transparent picture band devised by Reynaud. The position in cinematography was similar to that which obtained in the dissemination of learning before the invention of Gutenberg. Both books and moving pictures were practical by the slow and expensive method of hand production, but they could not become a universal force in civilization until some means of mechanical printing was discovered. A cheap transparent photographic film was doubly necessary in cinematography, it was necessary for the marvelously rapid picture taking required in the new science of movement, and it was needed still more for the reproduction of cinematograph images.

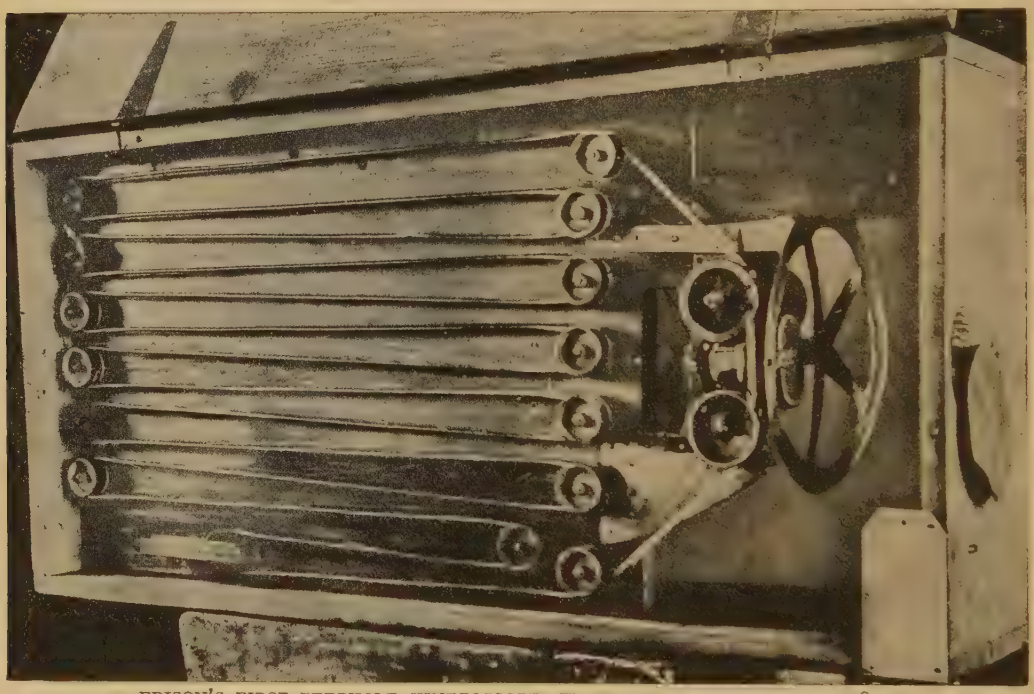
The search for the new film occupied for many years some of the most ingenious minds in the world. Various materials were tested. Some were impossible, and others defective; and finally the hopes of the experimenters became centered on celluloid. This, as is generally known, is a preparation of guncotton and alcohol, forming a thick, honey-like liquid, which is usually rolled out in sheets and dried. The sheets, however, were not thin enough to be used in cinematography, and the firms who manufactured them refused to make anything thinner.

They felt sure that it would not pay them, so they said, to set up special machinery that would be useless as soon as the temporary craze for celluloid films had passed. George Eastman, however, who did so much for the advancement of all kinds of photography, and who was then engaged in the manufacture of photographic plates, began to investigate the possibilities of a celluloid film and of a proper camera to use with it.

Many difficulties were encountered, both in the manufacture and in the use of such films and it was not until a comparatively few years ago that anything like perfection was attained. Many of us remember the early films which, after being developed and dried, rolled up as tightly as a lead pencil so that it was almost impossible to flatten them out for purposes of printing. That was only one of the minor difficulties, but that, like others, was eventually overcome both by Mr. Eastman and his associates and by the other firms who were experimenting along the same lines. Today we may use celluloid films with as much certainty of good results as if we were using glass plates.

It was in 1889 that the first really satisfactory films were produced. Then the way was opened for the development of the modern art of motion picture making, for the celluloid film furnished just the material for the negative and for the positive.

The credit for its adaptation to motion pictures is due to Thomas A. Edison. He had made a little machine for showing moving pictures, which he termed a "kinetoscope". But, having found that it was useless with the glass plates then employed in photography he had thrown it aside. In 1889, however, he heard of Mr. Eastman's discovery and, obtaining some of the new celluloid film, he succeeded in printing a series of photographs of movement on a continuous band. He placed the band in an improved kinetoscope, and animated photography was at last lifted from the field of scientific experiment into the realm of commercial success. Exhibited at the World's Fair at Chicago in 1893, the kinetoscope amazed and delighted the public. A nickel dropped into a slot in the little wooden cabinet containing the machine set the

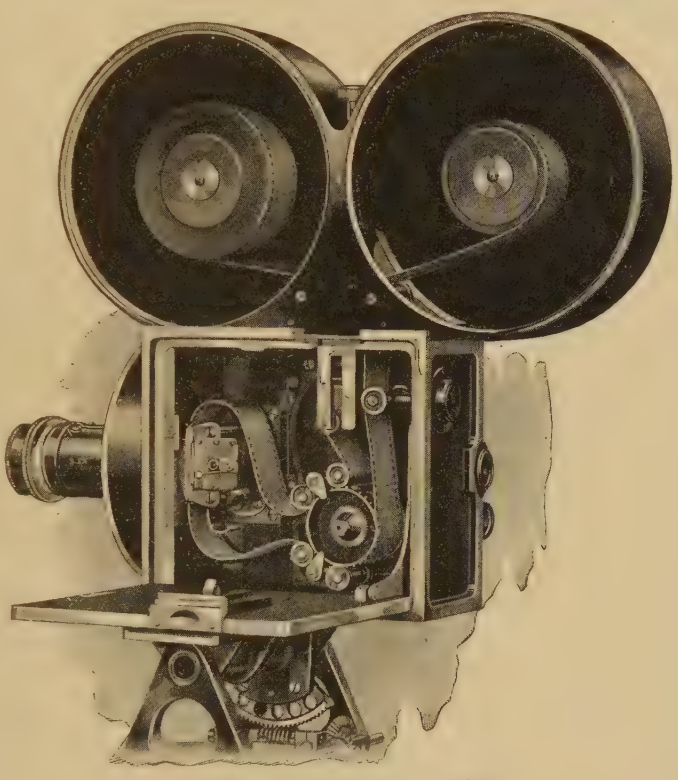


EDISON'S FIRST PEEPHOLE KINETOSCOPE, WHICH WAS COMPLETED IN 1890

mechanism in motion, then the sightseer looked through a peephole, and saw a strange spectacle that lasted for half a minute. Children skipped and danced, and men and women went about the business of life, and all their living movements were vividly shown by passing a film of photographs before the eye of the spectator at the rate of forty pictures a second.

The kinetoscope was simple in construction. It consisted of nine small rollers and two large reels. Moving between the rollers and the reels was a ribbon of pictures, forty feet in length, consisting of tiny photographs printed upon a transparent strip of celluloid film. As the ribbon passed from the first large reel to the second, it came between a magnifying lens and a small electric lamp and reflector. In front of the magnifying lens was a shutter, which opened and closed swiftly and continuously, making a break between each image. Power was supplied for lighting the lamp and moving the picture-band by a small electric motor, which worked automatically when the coin was placed in the slot. At first Edison had great trouble in keeping the film straight as it traveled over the rollers. But he managed to prevent it from slipping by cutting out of the band of film a considerable number of small holes, into which teeth caught and kept the ribbon straight.

Regarding the kinetoscope merely as a new kind of toy, Edison did not trouble to patent it abroad. So Robert W. Paul, a scientific instrument maker of London, constructed some of the machines to the order of two clients who had seen them at the World's Fair. The defect of the kinetoscope was that only one person at a time could see the picture in animation, and movements lasting more than half a minute were difficult and costly to produce. But Paul devised a special lantern through which the film was run, so that a large picture was thrown upon the screen. In France, Lumière et Fils worked on the same problem, inspired, like Paul, by the moving-picture toy of Edison. The Lumière cinematograph was the first of the two machines to arrive in the United States, where, in spite of all that Edison had done, the moving-picture toy with its peephole had not inspired any large and practical advance in popular animated photography. For some years England was the center of the progressive movement in cinematography, but now the majority of such films as are not of a topical kind are made in the United States and France.



MODERN MOVING-PICTURE CAMERA

This diagrammatic representation of the Bell & Howell camera shows the interior of the camera and magazine and the mechanism by means of which the film is carried from the front (feed) magazine past the photographing aperture and through the camera to the take-up magazine. The film is wound like tape on a spool. The turning of the camera crank (not shown) puts the entire mechanism in motion. The sprocket in the lower right-hand corner of the camera is made to revolve, and the film is moved lengthwise by the power applied to the hub of the spool in the take-up magazine. It is controlled on its travel through the camera and magazine by the engaging of the perforations in the film with the teeth of the sprocket.

OVER A HUNDRED PICTURES OF AN EXPRESS TRAIN, TAKEN AS IT FLASHES PAST

THIS SERIES OF PICTURES, SHOWING AN EXPRESS TRAIN PASSING A GIVEN POINT, IS REPRODUCED DIRECT FROM A CINEMATOGRAPH FILM

We all know how popular the motion-picture houses have become and what crowds they draw. Though this multitude enters the theaters in search merely of amusement, the moving picture is an education as well as an entertainment. Nearly all the history of the United States has been worked out into pictures ready to be shown on the schoolroom screen. In the geographical lessons, the children are taken to the various countries, first shown on maps, and then the life of the people and the scenery and industries of the nation are brought before their eyes.

THE CINEMA CAMERA AND BIG GAME

Simple reading and simple arithmetic are also taught by moving pictures. The construction and working of pumps and engines and other important mechanisms are shown first in workshops and then in machines photographed in motion, and partly made of glass so that the inside movements are clearly revealed. For teaching natural history the instrument is very effective. It is also calculated, when combined with lectures, to make history and geography a delight instead of a task. Some of our public schools find the cinematograph very useful in the latest and most difficult branch of study. Few people have any actual knowledge of those minute forms of life which occasion practically all the diseases to which the human body is subject. Outside the small circle of professed students of bacteriology, there is scarcely one person in ten thousand who has seen a microbe. Yet every one of us is actively engaged in fighting the agents of disease; and the individual and national struggle for health will not be organized for success until an intelligent knowledge of the conditions of this strange warfare is widespread.

Already, however, it is possible to conduct a campaign of enlightenment by means of the cinematograph. With the help of the ultra-microscope, Dr. J. Comandon, of Paris, has managed to cinematograph some of the most terrible microbes of disease. Their forms and motions are displayed with wonderful clearness on the screen, and their action on the blood corpuscles is also revealed. A demonstration of the trypanosome of sleeping sickness is shown on page 2786. Other films show how the little animal that lives in our blood protects us from our minute but deadly foes.

LIFE CAUGHT AT WORK IN MANY MOODS

A SCARAB BEETLE FORMING A PELLET

A SCARAB BEETLE PUSHING A PELLET

A TADPOLE JUST EMERGED FROM THE EGG

FIVE METAMORPHOSES OF THE FROG

A FAMILY OF HERMIT CRABS

A HERMIT CRAB OUT OF ITS SHELL

SENSITIVE PLANT WITH LEAVES CLOSED

SENSITIVE PLANT AFFECTED BY ELECTRICITY

SCIENCE AND THE CINEMA
The trypanosome of sleeping sickness shown on a screen.

The nice work of making moving pictures through a microscope requires great skill and, of course, special apparatus. An object is ordinarily observed under the microscope by transmitted light and must often be rendered visible by the use of some dye for staining. This is not practicable when a motion picture is to be made of a microbe, for instance, because the stain would kill the microbe.

Another field for the moving picture is in connection with the X-ray, giving a means of studying such hidden things as the processes of digestion and other functions of the body.

A new world of invisibility has suddenly become visible to mortal eyes. We can study the action of flight in the swiftest bullet more easily than with the unaided eye we can observe the motions of a tortoise. The entire science of ballistics has been thus revised. Very soon, in all probability, by combining a super-cinematograph with the ultra-microscope, it will be possible to study the molecular movement of matter. Even the astronomer has found the moving picture of great service in his science in studying that strangest and most beautiful of heavenly phenomena — the aurora borealis.

This use of the cinematograph brings out in a striking way the principal defect in the past of the machine as an instrument of science. It cannot show objects in all their natural colors. Ingenious and interesting as are the picture-plays and topical scenes and trick effects produced by the modern machines, they lack the one thing that Reynaud succeeded in achieving with his cumbersome apparatus in 1877. They reproduce the movements of life, but they fail to catch the full glory of its colors. This defect will doubtless be overcome in time. Much has been already achieved. Of course, it is possible to adopt Reynaud's method of hand-painting the images, but this is still very costly and laborious. Moreover, it takes away from modern moving pictures that quality of actuality which makes them popularly interesting and valuable from a scientific point of view.

THE SPEED OF CINEMATOGRAPHY — A BULLET PASSING THROUGH A SOAP-BUBBLE

The endeavor to obtain natural color motion pictures began with the introduction in England of "Kinemacolor" in 1908. In this process only red and green screens were employed. One picture was photographed through the red, and the other through the green screen; and this alternation of two of the primary colors continued throughout the film. There was no blue or violet actually in the pictures, and no true yellow. A blue tone, however, was partially introduced by a certain proportion of blue in the green screen, and by the use of an electric arc light in the lantern. The combination of these two factors compensated in a small degree for the absence of the violet screen. Yet the absence of pure yellows, true blues and deep purples was very noticeable, but the pictures in themselves were so new and interesting that the faults were for a time overlooked. But color pulsations, color fringing on quick moving objects, a predominance of reds and greens finally wearied the public; people suffered eye strain and headache, and the process died a natural death.

Prizma and the color movies

The next heard of color was the process known as "Prizma", a process similar to Kinemacolor, but with the color actually in the film itself, and not relying upon the special projector to obtain color effects. William Van Doren Kelley, technician to the company, devised a camera which, by means of prisms and lenses, would photograph both color images at the same time and thereby eliminate fringing of quick moving objects. The images were made on one strip of negative and not two separate films, the pair of pictures being superimposed one above the other. It was found that the lens system involved considerable loss of light, and this was compensated for by super-sensitizing the negative prior to use. Future experiments may result in dispensing with it entirely.

The printing of the negative was made on positive film but coated on each side with emulsion.

The printing itself at first presented great difficulties, because the two images or pictures had to be in exact register — a lack of it, even to one-thousandth part of an inch, being visible on the screen. This difficulty was overcome and satisfactory results obtained. The film was developed in the ordinary way and then bleached and dried. After drying it was floated on dyes, first one side and then the other, the dye being absorbed in correct proportion by the mordant or bleach, the result of the two dyed images being an exact reproduction of the original picture photographed.

During the period that Prizma was first operating, another process, known as Technicolor, made its début. Technicolor's method of photographing was by means of a camera containing a prism that split the photographed image in two. Printing was made on ordinary positive film in black and white, there being no visible color on the film, but only latent color values. A special projector was used in which the two pictures were projected through separate lenses, falling upon each other on the screen in register, giving the effect of color. When the register was exact, the results were good. There was no color fringing nor color pulsation, but the two images would continually separate on the screen, and would so stay until the projectionist was able to correct the register. The complicated projector was soon abandoned and a method of producing the color in the film itself evolved.

Up to this time there were five concerns in this country who were producing natural color pictures: Prizma, Technicolor, Kodakchrome (Eastman Co.) Colura and Artcolor (Kinemacolor). All of the processes used were two color schemes, the basic principles of each being very similar, but the method of application varying considerably. Several productions made by the first two have already been shown with success in this country and abroad, and further improvements in definition and lower cost are already in sight, or promised, almost certain to have a revolutionary effect on the moving picture industry as now practised.

The talking movies

A most important motion picture development in 1923 was the invention of the "Phonofilm", by Lee DeForest. It makes practical and commercially applicable the simultaneous production of vocal and optical films by insuring absolute synchronization. How it is done is described by its inventor as follows:

"*Recording:* An especially designed gas-filled lamp, called the 'Photion light,' is inserted in the moving picture camera a short distance from the usual objective lens. The light from this Photion tube passes through an extremely narrow slit and falls directly upon one margin of the film. This margin is screened from the picture itself so that only the light from the tube falls upon it. The film is driven continuously with an even speed, in front of this narrow slit, but with the usual intermittent step-by-step motion in front of the picture aperture.

"Now the light in the Photion tube is generated by the electric current which is passing through the gas inclosed therein, and its intensity depends on that of the current. Therefore, if a powerful telephonic current is passed through the tube the light emitted varies exactly in accordance with the strength of the telephonic current at any instant, and fluctuates in brightness hundreds or thousands of times a second in perfect rhythm with its pulses.

"This telephonic current originates in the first place from a special microphone transmitter, quite unlike the ordinary telephonic microphone but serving the same general purpose, which picks up the sound waves at distances of five to fifteen feet from the source of the sound, transforming them into very weak telephonic currents. The Audion amplifier is then used to amplify these weak currents 100,000 times to bring them up to sufficient strength to influence the Photion lamp.

"Thus we have three transformations — first sound waves into electric currents, then the amplification of these currents into light waves, and the registering of these light waves through the narrow slit upon the photographic film.

"*Reproducing:* The negative film, carrying picture and sound record, is now developed in the usual manner, but using a special developer to bring out the details of the sound record. Positive prints are made through a special printer to give the necessary light values for picture and sound record, and they are then run through a standard projector machine such as is found in any moving picture theater. An attachment which includes a small incandescent lamp and a highly-sensitive photo-electric cell, the latter being the invention of T. W. Case, is added to this projector but in no way interferes with its ordinary use. Between the lamp and the photo-electric cell passes the film as it travels through the projector. The light from the lamp is concentrated upon a tiny slit, similar to that described in the motion picture camera, and passes through the sound record which has been photographed on the film, and on into the chamber containing the photo-electric cell. The passage of the sound record, therefore, across this narrow slit controls the intensity of the light falling upon the sensitive cell.

"The photo-electric cell has this peculiar property — its electrical resistance at any instant is determined by the amount of light falling upon it. Therefore, as the film travels across the slit and the light is made to fluctuate hundreds or thousands of times per second, the electrical resistance of the cell varies in strict accordance.

"Connected to this photo-electric cell is a small battery for supplying current, which is therefore controlled by the light falling upon the cell, and thereby made to exactly reproduce the original telephonic current from the transmitter when the sound picture was first recorded. This new telephonic current, however, is extremely weak, and must be amplified again and again through a series of especially designed Audion amplifiers, until it is increased in power hundreds of thousands of times. It is then passed through loud reproducers, located behind or beside the screen upon which the picture of the speaker or the musical instrument is being shown, and in this way the reproduced sound appears to come from them.

"*Synchronism:* The Phonofilm process solves the problem of synchronism. The photograph of the sound and of the object are always together on the same film and always at the same relative positions thereon. If the film breaks it can be repaired in the usual manner, without impairing the synchronism. Standard film is used, and the reproducing attachment is designed for either the Simplex or Powers machine."

OUT OF DOORS FILMING AT UNIVERSAL CITY

Producing plants for photo-dramas are numerous and elaborately equipped. Southern California, on account of its mild climate and clear air, is a favorite locality for them, and the greatest is Universal City, the only motion picture municipality in the world, built early in 1915 in the San Fernando Valley, five miles north of Hollywood, a suburb of Los Angeles. Here there are some thirty producing companies at work, each distinct in personnel and direction, and each engaged on its own particular film. The output averages 150,000 feet per week. It is one of the most interesting places to visit on the Pacific Coast, and the observation galleries built for the convenience of tourists are crowded, the daily attendance often exceeding a thousand.

CORNER OF ONE OF THE STAGES AND THE VISITORS' PLATFORM AT UNIVERSAL CITY

There are eight stages, six open-air and two artificial light, giving between three and one-half and four acres of stage space. The largest is 500 feet long by 125 deep. Back of it is a double row of dressing rooms, running the entire length of the stage, and there is another single line of rooms devoted to the stars.

The city proper consists of some twenty concrete buildings with an equal number of wooden structures and others built of sheet or corrugated iron. One of the buildings is devoted to the administrative force. In another the laboratories, the most complete in the West, are located. There is a restaurant where 250 may be fed at a time. Other buildings are occupied by the technical, the property, the wardrobe, the art, and the fire and police departments, etc. There is a library, an information bureau and publicity department. The city owns and operates its own water system and has, also, its own theaters, where seven pictures may be projected at the same time, its own auto service, ice plant, and arsenal with an equipment of firearms from the flintlock down to the modern army rifle; tailoring establishment, blacksmith shop and a thoroughly modern hospital.

At the rear of the property, nearly a quarter of a mile away, is the "back ranch".

CAFÉ SCENE BEING FILMED IN THE HUGE ELECTRIC LIGHT STUDIO WHERE TWENTY COMPANIES CAN MAKE PICTURES AT ONE TIME

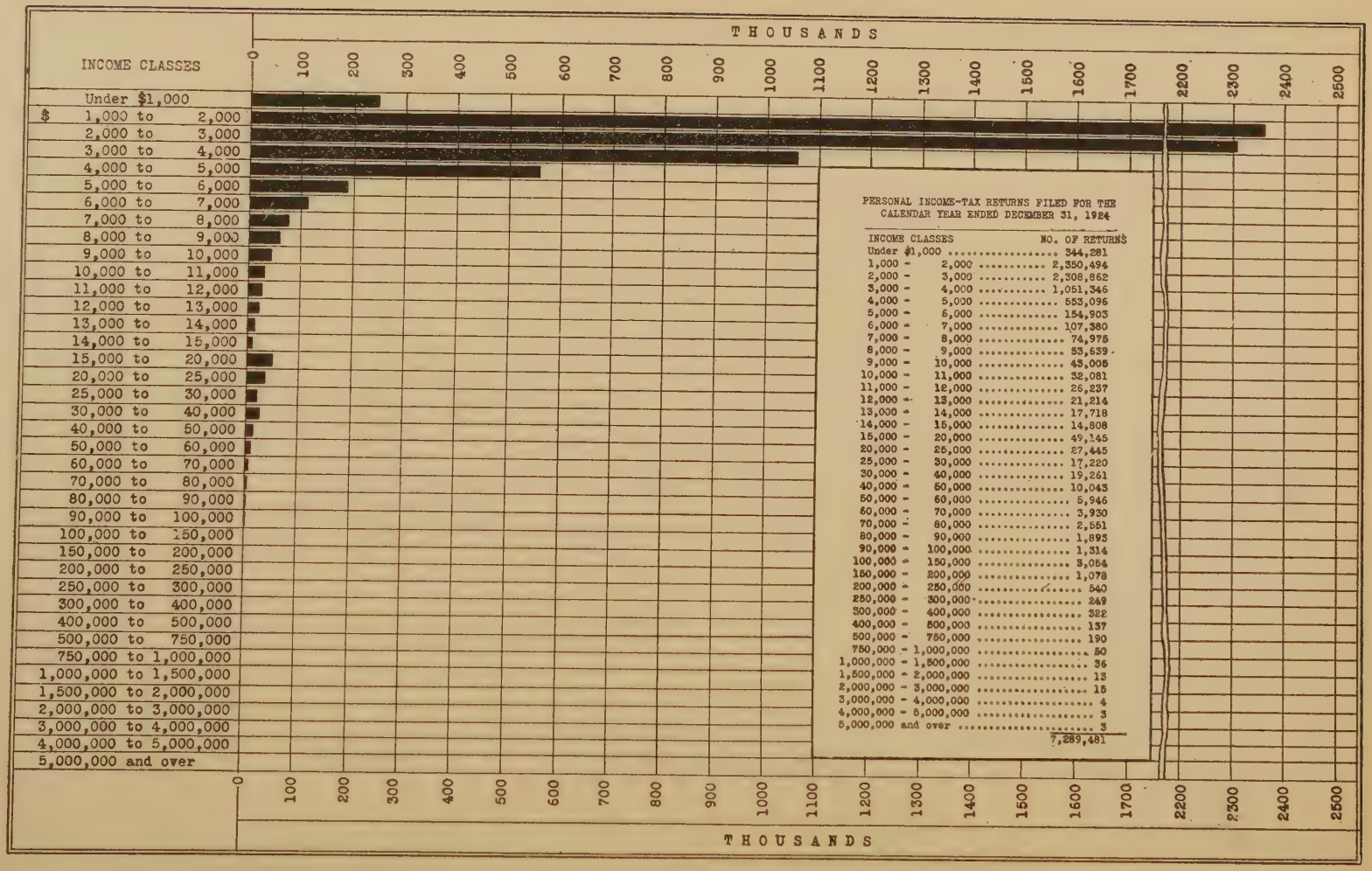
This comprises a group of buildings, an open-air stage, another restaurant, rows of dressing rooms, a zoo, cowboy bunk-houses, cavalry barracks, etc. It is here that the greater part of the open-air sets, street scenes and villages are constructed. The zoo is one of the most extensive of such privately owned collections in the state. Camels, wolves, lions, tigers, leopards, bears, monkeys and all the animals usually to be found in similar collections are there. Here, too, are paddocks of English thoroughbreds, corrals of western cow ponies and a herd of cattle used for feeding the animals, as well as a better breed for the restaurants.

There are few branches of industry which are not represented at Universal City. A corps of carpenters and scenic artists, concrete workmen, electricians, plumbers, cabinet-makers, harness and saddle-makers, blacksmiths, laborers — everything in fact that is to be found in the larger cities is included among the fifteen hundred inhabitants of this picture municipality. The plant is valued at several millions, and the annual expenditure is three million dollars.

A professor at the Berlin Military Academy has succeeded in obtaining moving pictures of a bullet striking a steel plate, which promise to revolutionize the science of ballistics. He invented a new kind of cinematograph camera, in which the film moved before the lens at the marvelous speed of one hundred and fifty miles an hour. The film was run over two steel cylinders, and somewhat more than two hundred and eighty feet of it passed before the lens in the space of one second. Light was obtained by a series of electric sparks, some of which only lasted one ten-millionth part of a second. Yet the pictures obtained at this tremendous speed, and with this miraculously brief exposure, were clear and well defined, and of the standard size. As a rule, he takes about five hundred consecutive pictures in one-tenth of a second, and then throws them on the screen at the rate of sixteen a second.

This is about two thousand times slower than the thing actually occurred. To put it in another way, the cinematograph enables us to magnify time in the same way that the microscope enables us to magnify space.

A BATTLE-SCENE IN WHICH 2500 MEN AND HORSES TOOK PART



PERSONAL INCOME-TAX RETURNS FILED FOR THE CALENDAR YEAR ENDED DECEMBER 31, 1924

INCOME CLASSES	NO. OF RETURNS
Under $1,000	344,281
1,000 - 2,000	2,350,494
2,000 - 3,000	2,308,862
3,000 - 4,000	1,051,346
4,000 - 5,000	553,096
5,000 - 6,000	154,903
6,000 - 7,000	107,380
7,000 - 8,000	74,975
8,000 - 9,000	53,639
9,000 - 10,000	43,005
10,000 - 11,000	32,081
11,000 - 12,000	26,237
12,000 - 13,000	21,214
13,000 - 14,000	17,718
14,000 - 15,000	14,808
15,000 - 20,000	49,145
20,000 - 25,000	27,445
25,000 - 30,000	17,220
30,000 - 40,000	19,261
40,000 - 50,000	10,043
50,000 - 60,000	5,946
60,000 - 70,000	3,930
70,000 - 80,000	2,551
80,000 - 90,000	1,893
90,000 - 100,000	1,314
100,000 - 150,000	3,054
150,000 - 200,000	1,078
200,000 - 250,000	540
250,000 - 300,000	249
300,000 - 400,000	322
400,000 - 500,000	137
500,000 - 750,000	190
750,000 - 1,000,000	50
1,000,000 - 1,500,000	36
1,500,000 - 2,000,000	13
2,000,000 - 3,000,000	15
3,000,000 - 4,000,000	4
4,000,000 - 5,000,000	3
5,000,000 and over	3
	7,289,481

CHART SHOWING BY INCOME CLASSES THE NUMBER OF PERSONAL INCOME-TAX RETURNS FILED FOR THE CALENDAR YEAR ENDING DECEMBER 31, 1924

THE ANNUAL WEALTH PRODUCT

The Income of the People and
Its Distribution Among Them

AN ACHIEVEMENT OF STATISTICAL SCIENCE

IN the last chapter we examined such facts as were available respecting the accumulated wealth of the United States, of Canada, and of other important countries. In the present chapter, we have to deal with a different, though related, subject: namely, the *annual* production of wealth, and the distribution of the annual wealth product among the people of the country. The two subjects are related because, of course, accumulated national wealth, or national capital, is created by annual increments of produced and saved wealth. As with an individual, so with a nation; capital is the resultant of a net difference between production and consumption; that is, it is built up by income and depleted by expenditures.

For a long time the United States had no reliable statistics of the distribution of incomes among persons or families, although, on the basis of the results of the decennial census of manufactures, agriculture and mining, it was possible for statisticians to make up fairly adequate estimates of the annual production of wealth. It was not until the United States adopted a federal income tax that trustworthy estimates of the distribution of incomes became possible. For our present knowledge of the size and distribution of the national income we are indebted to the National Bureau of Economic Research which published in 1921 its findings respecting the amount and distribution of income in the United States. The work of this research institution is itself a noteworthy example of the way in which science may be enlisted in the solution of economic as well as technical problems.

The bureau is a non-partisan institution. Its aim is merely to ascertain fundamental facts in its field, and to make its findings known. By so doing, the officials of the bureau state they hope "to aid all thoughtful men to base their discussions on objective knowledge as distinguished from subjective opinion". To insure impartiality, the directors of the bureau are chosen by such diverse organizations as the American Economic Association, the American Statistics Association, the American Bankers' Association, the Engineering Council, the National Industrial Conference Board, the American Federation of Labor, the Periodical Publishers' Association and the American Federation of Farm Bureaus. Professional economists and statisticians, bankers, accountants, business men, labor leaders and socialists are numbered among its directors.

In attacking the difficult statistical problem to which we have referred, the bureau made use of a simple, fundamental principle: the total amount of *wealth produced* during a year must be equal to the total amount of *incomes received* during the year. This will be clear to the reader if he will note, first, that for all of the wealth produced, so far as it is sold on the market, its producers receive money incomes, and second, that the money incomes of any year are expended (counting investments as a form of expenditure) for the wealth produced within that year. Certain adjustments are necessary to take account of marketable goods not actually marketed, as, for example, wealth produced and consumed on the farm. Account must also be taken of the fact that sales of land or

securities at increased values may create "income" which has no exact offset or counterpart in the "wealth product".

The bureau's statisticians made independent estimates of the national income or national wealth product by two different methods: (1) by sources of production, utilizing largely census results and similar material, and (2) by incomes received, utilizing income tax statistics and similar facts.

It is high testimony to the scientific quality of the bureau's work that these two independent estimates, made for each of the years from 1909 to 1919 inclusive, agreed very closely, the maximum difference between the two in any one year being 7 per cent. For the year 1916, the difference between the two estimates was one-tenth of 1 per cent! This is surely enough to show that the results reached by the bureau are entitled to an unusual measure of confidence. For this reason, we shall make them the basis of our own discussion.

Before discussing the details of income distribution in the United States it will be well for us to take a glance at the size of the annual wealth product of the United States as compared with that of certain other leading nations. Here again we shall avail ourselves of figures carefully brought together by Sir Josiah Stamp, which we have summarized in the accompanying table. It must be remembered that these are pre-war figures. An increase in physical production accompanied by a much larger increase in the general level of prices has led to a corresponding increase in the money value of the wealth product of all countries. Thus for 1918, the aggregate wealth product of the United States was not less than sixty billions of dollars, — not far short of twice what it was before the war. It is probable that not more than from 10 to 20 per cent of this extraordinary growth can be accounted for by an increase in the actual volume of the output of the products of the farms and industries of the country. The bulk of the increase — from 80 to 90 per cent of it — is merely apparent, being a result of the diminished purchasing power of the dollar.

Similar changes have likewise occurred, generally on a more violent scale, in other countries, for everywhere the war led to inflation of currencies and to depreciation of the value of money.

THE INCOME OF THE LEADING NATIONS: 1914

Country	Estimates Based Upon the Work of	Approximate Accuracy: Grade*	National Income, Millions of Dollars	Per Capita Income, Dollars
United States	National Bureau of Economic Research	I	$33,200	$335
United Kingdom	Bowley, Stamp	I	10,950	243
Germany	Helfferich	I	10,460	146
France	Pupin	II	7,300	185
Italy		IV	3,890	112
Austria-Hungary		IV	5,350	102
Spain	Barthe	IV	1,120	54
Australia	Official, Knibbs	I	1,260	263
Canada	Giffen	IV	1,460	195
Japan	Stamp	III	1,580	29

*Grade I. Estimate is not likely to be inaccurate to a greater extent than 10 per cent.

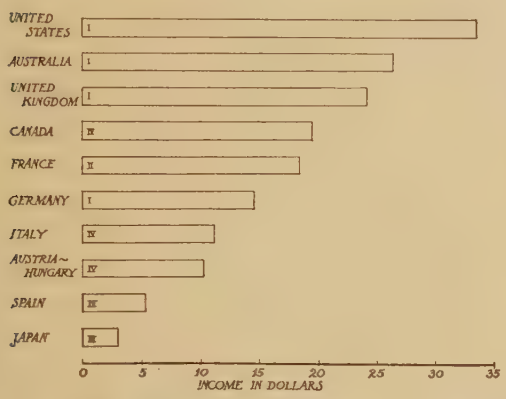
Grade II. Estimate is not likely to be inaccurate to a greater extent than 20 per cent.

Grade III. Estimate is not likely to be inaccurate to a greater extent than 30 per cent.

Grade IV. Estimate may be inaccurate to a greater extent than 40 per cent.

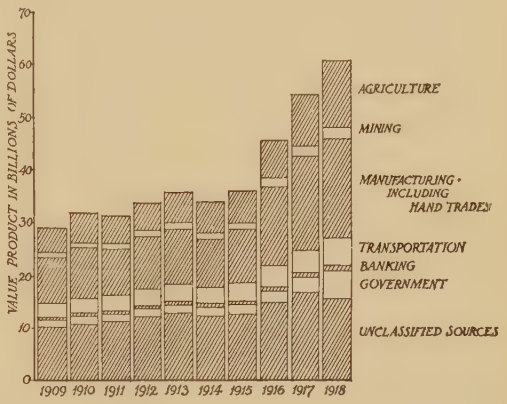
On the basis of the pre-war figures, which are more instructive than any yet available for the period after the war, the aggregate national income of the United States was three times that of either the United Kingdom or Germany, and four times that of France. This astonishing difference can be ascribed only in part to the larger population of the United States, for its per capita income was 38 per cent more than that of the United Kingdom, 80 per cent higher than that of France, 130 per cent higher than that of Germany, and three times as great as that of Austria-Hungary. Australia, whose per capita income was 80 per cent that of the United States, makes a better showing. The estimate quoted for Canada is, in the opinion of the present writer, much too low; he believes that the per capita annual product of Canada is probably as large as that of Australia. The very low figure assigned to Japan is a matter of interest.

Even before the war, the per capita income of less than $30 per year would have hardly sufficed for the meanest necessaries of life in either the United States or Canada. This astonishing figure is explained by the vastly lower standard of living that prevails among the peasants and laboring classes of that country.



PER CAPITA INCOME IN LEADING COUNTRIES, 1914

agriculture and mining taken together account for only between a fourth and a fifth of the national product, while manufacturing, including the hand trades, accounts for nearly a third. It will be understood, of course, that these figures are so compiled as to avoid duplication, so that the value of the agricultural and mining product is



VALUE PRODUCTS OF VARIOUS INDUSTRIES: 1909

These and other charts and material in this chapter are from "Income in the United States" by W. C. Mitchell and other members of the staff of the National Bureau of Economic Research, Inc. (Harcourt, Brace & Co., N. Y.).

Turning now to the consideration of the structure of the national income of the United States, we may note first of all the fact that the United States is by this test predominantly a manufacturing, rather than an agricultural, country. In fact, not again counted in the value of the product of the industries to which agriculture and mining furnish raw materials. The product assigned to manufacturing is merely the value *added* by the manufacturing process.

THE SOURCES OF WEALTH PRODUCT OF THE UNITED STATES

Source	Amount in Millions of Dollars			Per Cent Distribution		
	1900	1912	1922	1900	1912	1922
Agricultural Products	1,455	5,240	5,466	1.64	2.81	1.70
Mining Products	327	816	730	.36	.43	.22
Manufactured Products	6,087	14,694	28,423	6.87	7.88	8.87
Real Estate	52,538	109,237	176,415	59.35	58.63	54.99
Livestock	3,306	6,238	5,807	3.73	3.34	1.81
Transportation and Transmission						
Railroads and Their Equipment	9,036	16,149	19,951	10.20	8.66	6.25
Street Railways	1,576	4,597	4,878	1.78	2.46	1.52
Telegraph and Telephone	612	2,304	1,950	.69	1.23	.60
Motor Vehicles	——	——	4,567	——	——	1.42
Water Transportation	538	1,491	2,951	.60	.80	.91
Pipe Lines and Water Works	268	290	861	.30	.15	.26
Electric Light and Power	402	2,099	4,229	.45	1.12	.13
Unclassified Industries and Miscellaneous Income	12,372	23,145	64,576	13.97	12.43	20.12
Total	88,517	186,300	320,804	100.00	100.00	100.00

An estimate made some years ago by Dr. W. I. King indicates that in 1850 agriculture furnished about a third of the national income, while manufacturing was responsible for less than a fifth. The most notable change since 1850, if Dr. King's estimates may be trusted, is the decreasing share assigned to transportation, which formerly seems to have created something like 20 per cent of the wealth product, but which now can claim less than 10 per cent. This change is in the face of the enormous development of our transportation systems. The truth would seem to be that, despite the fact that we are using vastly more transportation, measured in ton-miles, than we did in the middle of the last century, our transportation is now so much more efficient and so much cheaper that it costs us, as a nation, relatively less than formerly. Seventy-five years ago something like a fifth of the income of the average citizen was absorbed by transportation costs; at the present time, the corresponding proportion is not more than a tenth. This is an excellent example of true economic progress: a product increased in quantity and bettered in quality, furnished at vastly decreased cost per unit.

One necessary limitation of these figures, as of all statistics of income, must be borne in mind. They take account only of such contributions to the national product as are sold for money, that is, for which a price is commonly paid. So far as goods and services are given freely, like the services of friendship or of parental care, they do not enter into the statement. Nor is the work which one does "for himself" taken into account, except where its money value can properly be estimated, as in the case of produce both raised and consumed on the farm. It is clear that in this way we omit some of the most important factors in real wealth-production, including, for example, the work of housewives. Sir Josiah Stamp has said:

"If we suppose that in one country one million wives stay at home, and one million women work in industry, and there are no domestic servants, the total 'income' will differ from that of a country where half the 'wives' work in industry, and half the other women are domestic servants in the homes of the absent wives, despite the fact that the total 'work' being done is the same in both cases."

On account of the interest attached to this particular item, the statisticians of the National Bureau of Economic Research attempted to make a rough estimate of its possible importance. It seems likely that there were some twenty million women in the United States engaged in housework in their own homes in 1918. If the average pay of domestic servants, including their subsistence, was, say, $500 per year, the total annual value of the housewives' services would on that basis amount to some $10,000,000,000. If the market price of work like that done by the average housewife was as much as $750 per annum, the value of the wealth product of the housewives of the country would have been approximately $15,000,000,000 — a contribution larger than the aggregate value of the agricultural product of the country and nearly as large as that of the factories of the country in the same year.

CHANGES IN THE WEALTH PRODUCT ATTRIBUTED TO DIFFERENT SOURCES

(Wealth Product in 1900 = 100)

	1900	1912	1922
Agriculture	100	363	378
Mining	100	249	223
Manufacturing	100	241	466
Transportation and Transmission	100	215	308
Real Estate	100	207	331
Livestock	100	188	175
Other Sources	100	186	521

Turning now to the statistics respecting the distribution of the national income among individuals, we enter a field of discussion in which advocates of one side and the other are accustomed to make assertions without troubling themselves about the actual facts. Socialists and other radicals have been inclined to paint a picture in wholly dark colors; advocates of the existing economic order have too often erred by using none but roseate tints.

What is Labor's share? No direct answer to this question can be given. But the investigations of the National Bureau of Economic Research show that payments to employees are equal to about one-eighth of the total value of the product in agriculture, to about two-thirds of the total in railway transportation, and to about three-fourths of the total in water transportation, manufacturing and mining. In large-scale industries, the pay of employees (including salaries of officials) amounts to about seven-tenths of the value of the product, the remaining three-tenths going to interest, rent and profits. Of the share going to employees, about 8 per cent goes to officials.

The accompanying table shows the way in which personal incomes in the United States were distributed in 1924. The table accounts for about $25,000,000 distributed among 7,298,481 persons. The figures include only those incomes reported to the Collector of Internal Revenue for the year 1924. The commonest size of income reported was between $1000 and $2000. This may seem surprisingly small, but it should be remembered that we are dealing with statistics of *personal* rather than family incomes, and that in many cases family incomes combine the incomes of two or more persons. It will be noted, furthermore, that the income group in which the largest *amount* of income falls is the group whose limiting figures are $2000 and $3000. Over one-fourth of all personal incomes fall into this class. As we advance toward the higher income groups, the number of persons in the group and the total amount of their incomes decrease rapidly. These facts have a bearing upon public policy with respect to income taxation.

It is quite clear that no system which relies largely upon heavy "super-taxes" imposed upon the exceedingly wealthy can tap the largest sources of public revenue. Moderate rates imposed upon the great mass of income receivers would be more productive than extremely high rates imposed upon the relatively few persons who have very large incomes. This does not mean that large incomes should not be taxed at a higher rate than moderate incomes; it merely means that if an income tax is to yield a maximum amount of public revenue it must rely largely upon fair and equitable rates reaching the millions of persons who cannot be counted among the wealthy.

1924 PERSONAL INCOME TAX RETURNS

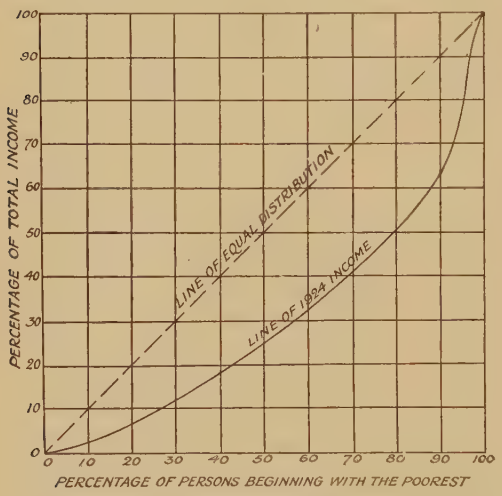
Size of Income	Numbers and Sums		Per Cents of Total	
	Number of Persons	Sum of Incomes	Number of Persons	Sums of Incomes
Under $1,000 *	319,831	$ 222,922,207	4.394	.88
Under $1,000	24,450	13,129,650	.335	.05
1,000– 2,000	2,350,494	3,441,614,242	32.205	13.75
2,000– 3,000	2,308,862	5,661,134,658	31.634	22.62
3,000– 4,000	1,051,346	3,560,402,718	14.280	14.22
4,000– 5,000	553,096	2,474,642,708	7.579	9.88
5,000– 10,000	433,902	2,965,766,075	5.945	11.45
10,000– 15,000	112,058	1,356,514,391	1.536	5.42
15,000– 25,000	76,590	1,469,615,391	1.049	5.87
25,000– 50,000	46,524	1,580,506,393	.637	6.31
50,000– 100,000	15,634	1,053,650,186	.214	4.20
100,000– 200,000	4,132	551,936,426	.056	2.15
200,000– 500,000	1,248	359,171,892	.017	1.43
500,000– 1,000,000	240	157,351,247	.003	.62
Over 1,000,000	74	154,852,709	.001	.61
Total	7,298,481	25,023,210,893	100.00	100.00

* Non taxable. Exemptions exceed net income.

CUMULATIVE DISTRIBUTION OF INCOMES: 1924

Amount of Income	Persons Having Incomes Above Stated Amount		Incomes Individually Larger than Stated Amount	
	Numbers	Per Cents	Sum of Such Incomes	Per Cents
Total	7,298,481	100.000	25,023,210,893	100.00
$ 1,000	6,954,200	95.269	24,787,159,036	99.05
2,000	4,603,706	63.146	21,345,544,794	85.30
3,000	2,294,844	31.442	15,684,410,136	62.67
4,000	1,243,498	17.037	12,124,007,418	48.45
5,000	690,402	9.459	9,649,364,710	38.56
10,000	256,500	3.514	6,683,598,635	26.70
15,000	144,442	1.979	5,327,084,244	21.28
25,000	67,852	.929	3,857,468,853	15.41
50,000	21,328	.292	2,276,962,460	9.09
100,000	5,694	.078	1,223,312,274	4.88
200,000	1,564	.021	671,375,848	2.68
500,000	314	.004	312,203,956	1.24
1,000,000	74	.001	154,852,709	.61

The same facts are tabulated in another form in the table showing the cumulative distribution of incomes in 1924. It appears that less than $1000 constituted less than 1 per cent of the aggregate amount of income. Incomes of over $2000 were 85 per cent of the aggregate income, while incomes of more than $5000 were 38 per cent, incomes of over $100,000 were 2 per cent, and incomes of over a million were only about half of 1 per cent of the sum of all incomes. When we turn to the distribution of income *receivers*, however, we find different results. Persons receiving incomes of over $2000 constituted only 63 per cent of all income receivers.

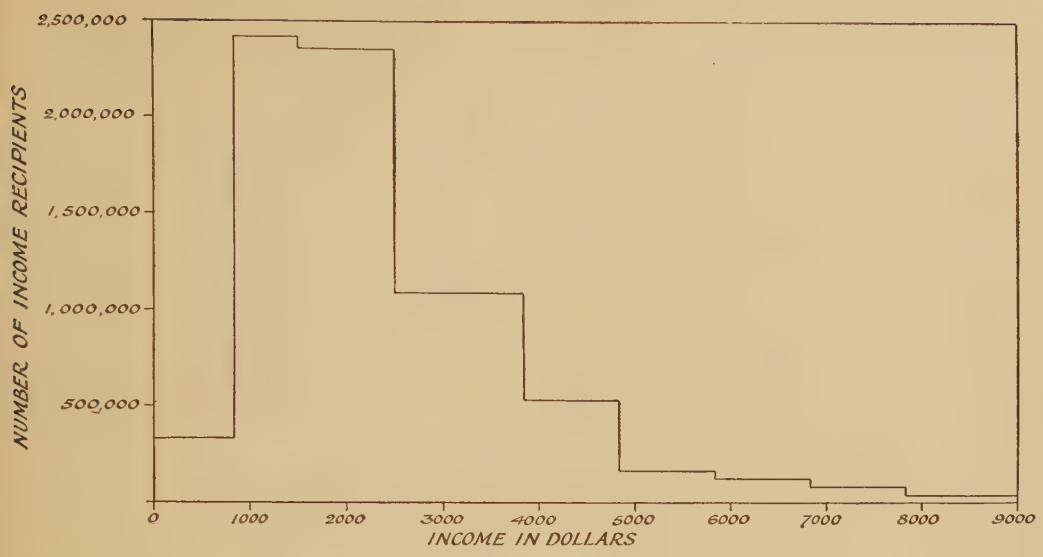


DISTRIBUTION OF PERSONAL INCOMES IN THE UNITED STATES IN 1924
As shown by the Lorenz Curve.

Those whose incomes were over $5000 belong to a favored 9 per cent of the population. Persons whose incomes were more than $100,000 constituted but seven hundredths of 1 per cent, while persons whose incomes were over $1,000,000 were only one one-thousandth of 1 per cent of all receivers.

Putting the same facts in another way, it would appear, according to the statistician, that the most prosperous 1 per cent among the income receivers got nearly 16 per cent of the total income; the most prosperous 10 per cent received about a third of the total; the group including the most prosperous fourth of all income receivers got about 50 per cent of the total income. Put in this way, the statistics may seem to indicate that income is concentrated to an alarming degree in relatively few hands. But a closer inspection of the facts gives them a different color. That prosperous 1 per cent of all income receivers includes all persons who get more than $25,000 per year. To get the most prosperous 9 per cent of the income receivers, we have to include everyone who has an income more than $5000. The most prosperous 30 per cent includes persons who are getting incomes of $3000 or a little less, and the most prosperous 60 per cent includes persons who are getting incomes slightly under $2000. All of these figures are summarized in what is called the "Lorenz curve", so named because it was first used by Dr. M. O. Lorenz, statistician of the Interstate Commerce Commission. Both the vertical and horizontal scales represent per cents ranging from zero to 100. The horizontal scale corresponds to income receivers, the vertical scale measures per cents of the sum of all incomes. Thus, for example, a point which we may take arbitrarily, such as the point located by measuring three squares toward the right on the horizontal scale, and two squares upward on the vertical scale, would indicate both 30 per cent of all income receivers and 20 per cent of all incomes. Now it is clear that if all incomes were of exactly equal size, 10 per cent of the population would have 10 per cent of the income, 40 per cent of the income receivers would have 40 per cent of the total income, etc. So the "line of equal distribution" on the diagram would represent this hypothetical situation, for the points through which it passes are equal distances from both the vertical and the horizontal scales. The actual distribution of incomes in 1924 is indicated by the curved line on the chart. The extent to which this line departs or curves away from the line of equal distribution may be taken as an index of the degree of inequality of the distribution of incomes in the country.

The defect of this Lorenz curve is that it lends itself to misinterpretation. Like the tables of the cumulative distribution of incomes on which it is based it compares



FREQUENCY DISTRIBUTION OF PERSONAL INCOMES IN THE UNITED STATES AS SHOWN BY THE INCOME TAX RETURNS FOR THE CALENDAR YEAR 1924

actual distribution of incomes with an impossible and really absurd state of affairs in which every person gets just as much income as every other person. A dead level of equality in the distribution of incomes is an impossible ideal. It is hardly ever urged even by extreme radicals. Some measure of inequality is necessary by reason of differences in ability and in energy. Incomes in an ideal state need not, perhaps, be absolutely proportionate to ability only, but there must at least be differences enough to serve as prizes or incentives for the abler and more energetic.

The chart of the "frequency distribution" of income is much less likely to be misleading. On this chart, the horizontal scale merely represents the different sizes of incomes, beginning with zero at the left, and increasing by uniform intervals to the maximum income at the right. The vertical scale represents the number of income receivers. Thus, a vertical distance measured upward from a given point on the base line or horizontal scale represents the number of income receivers who have incomes of the size indicated by that point. The diagram appears made up of "steps" merely because the statistics are for income *groups*.

However, if these groups were exceedingly small, that is to say, if, for example, there were a difference of only a dollar or ten dollars between the upper and lower limits of each income group, the diagram would appear as a fairly smooth curve.

Now the most striking aspect of this diagram to one who is a student of statistics is the general similarity of this curve of frequency distribution to many other sorts of frequency distribution curves that are found in nature. If its center were moved toward the right so as to fall at about $4000 rather than at about $1000, and if the curve were symmetrical instead of being much steeper on the left than on the right, it would be an example of what is called a "normal frequency distribution". A normal frequency distribution is like the "curve of errors" or the "probability curve". If the distribution of incomes were purely a matter of chance, we should expect that the statistics would reveal a normal frequency distribution. If, moreover, incomes were exactly proportionate to the difference in ability, and if ability, like many measurable physical traits, were itself distributed "normally", we should again expect that incomes would be distributed with normal frequency.

The fact is, however, that the curve is distinctly "skewed". The real extent of its skewness is not shown in the diagram, which does not extend above $9000, while incomes run up to many millions of dollars. In order to include incomes of a million dollars, the diagram, if drawn on the present scale, would have to extend to the right 100 times as far as it does! Long before reaching that point, however, the curve, if drawn on any practicable scale, would have come so close to the base line as to be indistinguishable from it. It is clear, then, that the incomes most frequently found are very much nearer the minimum than the maximum income. It also appears that the small incomes are huddled together, as it were, that is, that the differences in the incomes of persons in the lower part of the income range are extremely small, and that these differences increase with undue rapidity as the view is shifted to excessively higher income groups.

The alarming thing in these statistics of income distribution is not the extent of their departure from a condition of absolute equality — for some measure of inequality is inevitable in any properly organized society — but rather the general skewness of the income curve. The problem of poverty and the problem of great fortunes are the problems of the lower and upper limits of this income curve. Even more serious, however, is the fact that the extent to which the curve departs from normality throughout its whole extent seems to reflect the presence of a high degree of inequality in the distribution of opportunity.

Another way to put the whole matter may be helpful. We should expect in any properly organized society that incomes of moderate or "average" size would be more common than either extremely small or extremely large incomes. This, we may be fairly sure, would be the case if incomes were proportioned at all closely to the different abilities of the different income receivers, and if these different income receivers enjoyed anything like equal opportunities. Of course, the "spread" of income distribution, that is, the extent to which incomes in general are larger or smaller than the average or most common size of income, is also a matter of importance. The smaller the spread, that is, the greater the degree of closeness with which incomes are grouped around the average income, the less will be the real inequalities in the distribution of wealth.

Now the difference between this distribution of incomes in an ideal state of society and their actual distribution in the United States is not so great as to indicate that things are wholly out of joint, that nothing remotely approaching equality of opportunity exists, that there is "no justice in the world". But on the other hand, the skewness of the curve of income distribution, the concentration of large groups of people just below the average, and the way the curve stretches on so far toward the right by reason of really absurdly large incomes, indicates that we have not fully solved the problem of social justice, that even in our democratic social organization real inequalities exist, and that one's income, while partly a matter of deserts and earnings, is likely to be determined to some extent by the advantages of inherited wealth, or by the disadvantages of being born in poverty or of having before one only a "blind alley". Equality and inequality, justice and caprice, are undoubtedly present together in our existing economic order. The actual facts in the case give little comfort either to revolutionary radicals or to extreme conservatives. They indicate that the structure of our economic life is fundamentally sound, that it would be foolish to wreck it and attempt to erect a new structure based on nothing better than revolutionary theories and class prejudices. But it indicates also that we should not rest satisfied with things as they are, that the structure must be repaired and improved. In this work, we shall do well to keep constantly in mind the fact that the knowledge which science yields affords the only sure basis of permanent progress.

THE PROBLEM OF POVERTY

The Changing Destinies of Rich and Poor
Only the Forms of Stable Social Structure

AN EVIL THAT CONFRONTS THE WHOLE WORLD

IT is now pretty generally admitted that the industrial organization of the civilized world will have to be improved. A very large number of working people in the principal countries are unable to reach the standard of life necessary for themselves and for the race generally. The creation and the development of new industrial forces have profoundly disturbed the position of various classes of labor. In some important cases, also, a once powerful and wealthy class of people, the landowners, has suffered seriously through economic changes. In England, the typical and extreme example of an industrial nation, the landed gentry were formerly the dominant class, economically, politically and socially; this position has been lost through the double process of the decline in the rental value of agricultural land and the growth in wealth and power of the leaders of new forms of industry. This, however, is hardly to be regarded as a national tragedy; it will merely end in the displacement of the descendants of a former aristocratic stock by a plutocracy of new origin, a thing which has happened before. Many a descendant of the conquering Norman is probably now working as a simple laborer on the domain of his ancestors, and very likely numerous scions of the merchant nobility of the fifteenth and sixteenth centuries have also fallen back into the working class. Such changes, generally speaking, are a symptom of national strength rather than of national weakness. They indicate freedom of opportunity and a connection between success and merit or failure and demerit which tends to remove from the modern problem of the division between rich and poor some of its worst features.

In the North of our own country similar changes, though of a less extensive nature, have taken place. We have never had a permanent landed aristocracy, but the hundreds of abandoned farms still to be seen over the New England and Middle Atlantic States, and the thousands more which are worth today but a small fraction of the cost of the improvements upon them, attest the rigors of a transitional period. In the South, we find a closer approximation to English conditions. Here, too, the large estates or plantations of ante-bellum days have rapidly disappeared and the old landowners have lost a large share of their social prestige and political power to adventurers from the North or new men who have climbed from the ranks of the "poor whites". In the United States it has hitherto been the rule even more than in Europe that there is no permanent class of rich or poor, and this is rightly one of the main sources of our pride in our social and political system. We have, indeed, a few self-styled "old families", but they really go back but a little way, as the historian counts time, and "from shirt-sleeves to shirt-sleeves in three generations" has become an adage. Only the forms of social structure are stable; the individuals that temporarily embody these forms gradually but constantly change their positions in the course of generations.

On taking a long survey over the history of race, we find a succession of transformations which have kept the upward and downward currents constantly flowing with no long periods of social stagnation. Let us put it that the community from which the settlers of this country so largely came had the structure of a pyramid. At the bottom were the serfs, originally composed of the

Iberian agriculturalists, descendants of the inhabitants of western Europe in prehistoric times. They were somewhat small in stature, with brown eyes and dark hair, and though more civilized in the pacific sense than the Celts, were conquered by the superior military power of the latter. Mingling with them were Celtic Britons and Anglo-Saxons, who, by defeat or other misfortune, lost their political or economic freedom. The Danish invasions of England threw a considerable part of the Anglo-Saxon people into a state of subjection, and the Norman Conquest quickened the decline from power of the English tribesmen. The upshot was that Iberian, Briton, Englishman and Dane were at last crushed together and consolidated into the broad, strong base of the pyramid.

New causes for change in social pyramid

It would take too long to trace in detail the various movements upward and downward through the social pyramid that often led to an exchange of position between serf and aristocrat, trader and noble. We have seen in another chapter how the industrial revolution gave men new opportunities to rise and supplant the old aristocracy. Comparatively few of the leaders in that revolution belonged to the nobility. It is generally true that luxury sterilizes and enfeebles a noble stock, while the struggle against difficulties on the part of the working classes develops ambition and character and sharpens the mind. It is likely, however, that causes long unrecognized in political science helped to set up the ascending and descending currents of change in the social pyramid. For instance, it has recently been found that persons of Iberian characteristics are more resistant to certain diseases than the fair-haired, light-eyed northern races. In the urban civilization of the modern era, they are winning by reason of the fact that they are less subject to certain infantile maladies than are the newer elements of the Anglo-Celtic races. So it seems possible that their remarkable strength of constitution may have continually benefited them amid the deadly epidemic and endemic diseases of earlier times.

The mistake of regarding social politics as involving class warfare

However this may be, it is a matter of verifiable fact that poverty and riches, servitude and power, have been individual traits in our civilization. They have not been class characteristics: they still are not class characteristics. Thus, in an historic view it is misleading to talk in our country of class warfare. What passes for class warfare is only a temporary struggle between temporarily united groups of individuals, some in the ascending movement for the time being, and some in the downward movement. A rich, powerful and enlightened man of our present generation who engineers some social reform or the welfare of the poorest working class may unconsciously be working for the benefit of, among others, some of his great-great-grandchildren. In the same way, a labor representative who tries to hold a just balance between the national interests of the employing class and the immediate necessities of the working people may be establishing a precedent in legislation from which some not remote rich descendant of his will eventually profit.

Of course, these considerations cannot wholly remove from the struggle between the actual classes of our present society all its sectional bitternesses. Individual needs and individual prejudices are bound to animate the disputes between capital and labor, and subtly to influence the political conflict between declining aristocracy of landowners and a rising plutocracy of financial and industrial leaders. Yet when we are able to recognize that the meek do sometimes manage to inherit the earth, even if they in turn become luxurious and overbearing in their period of success, the social scheme takes on a complexion of more justice and freedom.

And especially, considering that the well-to-do classes of the present day are much less fertile than the laboring populace, we shall not be inclined to agree with Mr. H. G. Wells in his statement that "the gradual widening of the present merely temporary and social difference between the capitalist and the laborer is the key to the whole position".

Inheritance that comes to the working class through their greater fertility

The epithet of "proletarian", given in scorn to the class that serves the State not with property but with offspring (proles), is really a title to ultimate victory. The man of property in ancient Rome who so stigmatized the poor laborers around him has vanished, but the descendants of those laborers now form a flourishing part of the population of modern Italy. For centuries they have climbed to places of dominion; and possibly it was they who first instituted, in small and scattered industrial centers, the modern democratic movement that is now sweeping through the world. Everything at present makes for impermanence in the social status of the stocks of a society. Only one thing could take away from the working classes the natural advantages they possess over the less fertile propertied classes. And that one thing is a want of proper nourishment. If the base of the social pyramid continually grew weak in actual bodily strength, then nothing but the invasion of a mighty and more virile race could prevent utter decadence.

The selective effects of migration, especially between Europe and America

In England and other countries of western Europe the danger of actual under-nutrition at the present time is probably greater than it is in the United States, and much light can be thrown on this and other problems confronting Europe by a study of American history. It is estimated that first and last about twelve million people have emigrated from Great Britain to the United States alone, which is to say, about one and one-half times the population of the former country at the time of the Revolutionary War. When we add to these the drain to Canada and the other British Dominions and to every land where opportunity was beckoning to the adventurous spirit, the movement is entirely without parallel in the history of mankind. It is not only the numerical drain in population which is important, but the selective effect on the original population must have been very great. The younger nations have in general attracted the more vigorous, alert and adventurous spirits. The fiery temper shown by the colonists in Revolutionary days, out of all proportion to their real grievances, is best accounted for by the fact that it was mainly the hot-heads or people with a grievance real or imagined who had come to this country, often under the special encouragement of persons in power who found them troublesome in the mother country. Meanwhile most of the hopeless, apathetic, shiftless failures remained to increase their kind at home.

A new danger to society in the increased numbers on the hunger line

Then the progress of mechanical invention and industrial organization has aggravated the difficulties of the failures. In the earlier, simpler age, standards were relatively rigid and the scale of living as well as the relations of man to man was fixed by nearly unalterable custom. In the words of Sir Henry Sumner Maine, the law of status prevailed. Under such circumstances even the weak and incompetent had work assigned to them which at least brought in sufficient food to enable them to hand on their physical constitution unimpaired to their children, however mean their fare and surroundings might be. With the transition from the régime of status to that of free contract, however, the situation is changed. Here the race is to the swift with no mercy shown to the laggard. Not only the inherently incompetent, moreover, are ground down to real suffering; so swift is the race that many who are incapacitated by accident — a lack of education or of opportunity, or a passing blindness to the great changes in industrial affairs — are unable, when they have stumbled once, to recover their places. So they keep falling out with weak and empty hands, leaving their children terribly handicapped by actual under-nutrition as well as a disadvantage in situation.

It is again to England that we must go to see exemplified on the most extensive scale the tendencies inherent in industrialism and free economic competition, but conditions in the other advanced nations are different only in degree.

Not until recent years has a serious attempt been made to define poverty scientifically, and even yet there is no close agreement among students upon the fundamental question of the food requirements of the human body. In the United States, moreover, statistics are not available for a careful application of such standards as we have. The least observation, however, is enough to show that in all the civilized nations, particularly in the great modern industrial cities, large numbers stand constantly on the hunger line and respond with terrible sensitiveness to the movements of prosperity and depression in industry at large. Very little is needed to compel them to go on half rations. A slight rise in the price of common necessities scarcely felt by the ordinary householder means to them semi-starvation. Naturally the children suffer most. The health of the bread-winner must be maintained as far as possible, or the family goes to ruin and the poorhouse. So the children, and the mother of the children, and the baby to which she has not yet given birth, fall a prey to the weakening, sapping vampire of famine.

The grave handicap of the children of the poor

That is to say, the second generation of these laborers of the lower ranks set out in life with a heavier burden than even their fathers bore. And so the stock decays. If this decaying stock were but a small part of the human strength of modern nations, the problem it presents would still be grave and heart-breaking. But in England, where careful observers employing exact methods of investigation have studied the problem, it has been shown that about one-third of the urban population of the country live constantly below the minimum standard of physical efficiency. In Berlin, the dietitian Johannes Fischer computed in 1885 that 85 per cent of the population of the city were living below the physiological minimum. This was probably an exaggeration, as it is difficult to determine exactly what the minimum is, and in any case, conditions since then undoubtedly improved until the cataclysm of war. The best data extending over any considerable period of time are those of the great statistician Engel, for Belgium. The three general classes of food material necessary for bodily maintenance and growth are protein fat and carbohydrates. Careful budgets of nearly two hundred working-class families, collected in 1853, showed that the workers of Belgium were getting on the average nearly the full amount of carbohydrates, but only about two-thirds the amount of protein, and one-half the amount of fat, which the bodies of their families actually required. Later investigations, especially a comprehensive one in 1891, showed much improvement, but conditions were still far below what we should consider tolerable.

In our own country the most we can say is that poverty is probably less extensive than in England. Wages are normally higher here and the cost of living not appreciably dearer. A fair index to the economic welfare of a family is the proportion of the total income which is expended for food, the fraction of course decreasing as the income rises. In the Belgium family budgets studied by Engel, the average percentage was around 65; among working-class families in Saxony, the same author found it varying from 62 in the poorest down to 50 per cent in the families in easy circumstances. In the city of York, in England, Mr. Seebohm Rowntree has made the most exact investigation ever carried on in this field, actually visiting every home that did not keep servants in a population of over seventy-five thousand. These he divided into three classes, those living in "primary poverty", that is, having insufficient income for the bare necessities of life, those in "secondary poverty", who would have had enough were not their incomes for some reason or other not devoted to the requisites of life, and thirdly, those above the hunger line. He discovered that 7230 persons, or 10 per cent of the population of York fell into the first class, and that the second group added another 17 per cent, so that 27 per cent, approximately, had annual incomes inadequate for the meagerest subsistence. At the same time Mr. Charles Booth, employing an equally careful method in London, estimated the city's poor at 30 per cent.

In the United States the Bureau of Labor Statistics has carried on some very extensive investigations into living conditions. The proportion of total income expended for food has been rising with the increasing cost of living, but was only about one-half in the lowest division of incomes, those under two hundred dollars. Conditions here are not strictly comparable with those in Europe, however, as food undoubtedly costs less relatively to other things.

Industrial conditions, other than mere wages, worse in America than in Europe

Even here we have no cause for self-congratulation. Estimates as to what was necessary for maintaining an average industrial family in decent living conditions for the year 1918 varied around $1500, though some were higher as, for instance, that of the Philadelphia Bureau of Municipal Research, at $1637. The statistics of income in the United States reveal the startling fact that 55 per cent of the persons receiving incomes were below the $1500 level that year. Concurrently the most prosperous 10 per cent of the population had 35 per cent of the income, of whom the upper tenth were receiving 26 per cent of the total national income. Moreover, wages do not tell the entire story, and some other industrial conditions are worse in the United States than in Europe. Thus it is the general opinion that in this country the pace set is in general harder, and in consequence Americans work themselves out at an earlier age. It is certain that the fluctuations in industrial conditions are more extreme here and the waves of unemployment much worse. There is a continual recurrence of depressions such as that of the winter of 1914–15 and 1920–21, when great numbers are kept alive by recourse to the "bread line" in our great cities, and thousands are constantly hungry and cold. Again, industrial accidents are much more frequent with us, and we have been behind European countries in providing either for their prevention or for insurance against them to protect the dependents of our workers. In one year one employee out of every 400 on American railways was killed outright and one out of 24 injured.

Undernutrition, even as an affair of pure business, a matter of national interest

Now, as an affair of pure business, the nation cannot afford to look idly upon the waste of its human resources through undernutrition. It is flesh and blood, brain and soul, that have made us and must keep us what we are. We may hold a temporary advantage in our incomparable wealth of natural resources, but our ultimate standing in the world will depend on the manner of manhood we possess. It is imperative that the nation face as a nation the problem of conserving its human resources, in comparison with which all other conservation is of secondary importance. Something has actually been accomplished in this direction by the safety movement in the United States. Largely due to it industrial casualties were decreased, for instance, in the mineral mines from 1918 to 1919 by 26 per cent. But even then out of each thousand employed there were in the latter year 231 injured and 3 killed.

Difficulty of forcing up wages beyond the natural competitive adjustment

That the national consciousness is cognizant of the critical character of the situation is shown by the progress of minimum wage legislation, and the agitation for a fairer distribution of wealth. It seems obvious, at least on a superficial view, that the remedy for the evil is to raise wages, and no doubt a general increase in the wages of the lower class laborer would save his children from becoming a decaying stock. But waiving the fact that a part of the actual evil is due to the unwise spending of money now received, there are other difficulties in the way of this facile solution of the problem. It is easy to assume in an uncritical way, as is done by a certain type of agitator, that if the present income of society were better distributed there would be plenty for all, while the surfeited upper classes would be gainers rather than losers in real welfare. Looking at the matter first from the most general standpoint, we see that this view very much exaggerates the amount of superfluous expenditure by the rich. A few persons living in conspicuous luxury attract

much attention, but when we come to compute how much their excess spending would amount to for each of the millions who are below the proper level of comfort and decency, we find that we must go deeper. An American manufacturer writing on the subject recently put the case in a very graphic way. He pointed out that in establishments such as his own the yearly wage bill is on the average not far from the amount of the capital invested. As the average rate of return on the investment is not over ten per cent at the outside, it is clear that a general increase in wages of ten per cent would obliterate not only all profit but all interest on investment as well. From the report of a general inquiry into industrial profits in Massachusetts in 1890, a recent French writer computes that the income of the industries in that state would not quite suffice to pay five per cent interest on the capital invested and ordinary salaries for their work to those who now get their pay in the form of so-called profits.

The socialist idea of equal distribution of income not so good

According to the very careful estimates of the National Bureau of Economic Research the per capita income for the United States in 1918 was $586. In other words an equal distribution of income which has been expected by the socialists to do so much to alleviate human suffering, if actually brought about, would afford a rather meager income to each individual. No doubt a large body of consumptive needs which now go unsatisfied and so occasion a great deal of suffering would be satisfied under such an arrangement. But the diminution in the amount of saving consequent to the change might diminish productive efficiency enough to put the ordinary workingman ultimately in a worse situation than before.

The disadvantageous position in this country of the recently arrived immigrant

To be sure, a general and sweeping increase in wages is not required, but so large a proportion of our workers are forced to live below a decent minimum standard, and many of them so far below, that a mere redistribution of income in the various industries cannot solve the problem. In the struggle between the employing class and the working people wages may in some cases be raised through the use of the ultimate weapon, the strike, but it cannot prevail to any great extent against the economic forces of the world. Only such remedies can be generally effective as work to increase the productiveness of industry. Low wages and the low standard of life are interconnected, and must be advanced together by measures which act indirectly through securing a higher quality of human beings. Even in the higher class, well-organized trades, there are definite limits to what can be achieved by such expedients as the strike; and this remedy is scarcely applicable at all in the case of the poorer paid workers, including most of those immediately under discussion, who fail to satisfy their actual physical needs. These are almost entirely unorganized, and their economic weakness, together with the various handicaps to which that weakness itself is due, often make them unorganizable. In this country the situation is greatly complicated by immigration. Most of the worst "sweated" of our workers are the recent arrivals from Europe and their families. Ignorant of our country, its opportunities, customs and language, they are at a disadvantage not merely in doing such work as our industrial organization offers, but still more so in finding such places as they could fill. Crowding together in the great cities, they are an easy mark for the padrone and his ilk and fall a prey to the grossest exploitation. In addition, there are hundreds of thousands of "birds of passage" with no thought of any but a temporary sojourn over the crest of a wave of prosperity, or perhaps through a single work season. These laborers are naturally but little interested in making a stand for better conditions at the expense of any present sacrifice, and are often willing to live temporarily at a scale which no one would consider as a permanent status and which the American workingman rightly regards as humanly impossible. The result is a form of competition which is permanently disastrous to the American working-class standard of life.

The complicating effects of international and interstate commercial competition

Immigration is only one of the ways in which the wide range of competition in modern world-wide industrial organization makes itself felt. The rapid improvements in means of transportation and communication have widened the market for all except the bulkiest and crudest commodities until it includes the whole civilized world and much of the uncivilized. With this growth to all-inclusiveness in the size of the effective economic unit, political organization has not at all kept pace; even that unity of thought and feeling which would make such a political system possible must apparently take several more generations to achieve.

As an illustration, we may take the great cotton trade of Lancashire, that furnishes one-third of English manufactured goods and where very low wages are paid. The cottons are largely exported to the Orient, and as the purchasers are extremely poor, they cannot pay prices much higher than those now received. If prices are raised in order to pay higher wages to the English mill hand, sales will fall off and actual unemployment succeed upon employment at the present low wage. More serious still, other industrial nations are manufacturing cottons for the world market, and there must be a tendency for that nation whose working people produce the most goods for the least wages to beat the others in the competition. To be sure, this does not mean that it can pay a nation in the long run actually to under-nourish its workers, but to prevent this mutually ruinous competition calls for some sort of concerted action; and in the present stage of international politics this is extremely difficult to secure. Beginnings of a hopeful sort have been made recently through the International Labor Office of the League of Nations and through certain conferences held on the subject in accordance with the provisions of the peace treaty. The Washington conference in 1919, in which the United States was a participant though not a member of the League of Nations, adopted a long series of recommendations with regard to the extension of the 8-hour day and the 48-hour week, the prevention of unemployment, and the conditions of the employment of women and of children. A second conference at Geneva in 1920 extended the list of draft recommendations, and in 1921 the Geneva conference thoroughly revised the Labor Office on a sounder basis. It must be understood that the conferences are merely advisory, and in this respect are not so notable an advance over the earlier covenants made in Paris in 1886, at Berlin in 1890 and again in Paris in 1900. What is most encouraging, however, is the alacrity with which most of the participants have begun to apply in actual legislation the recommendations adopted. The Labor Office, moreover, really acts effectively through its occasional studies and *Official Bulletin* to enlighten legislation and engender a spirit of international solidarity among labor.

Within our own country we have something like the international situation, mitigated in some ways but intensified in others. Social legislation is largely in the hands of the states, which in many respects are like forty-eight separate and competing commonwealths. The authority of the national government in the matter is virtually limited to the power conferred upon Congress by the Constitution to regulate trade and commerce between the states; and even through liberal construction of this power by the courts may go far toward bringing some phases of the problem legally under unified control, the opposition of American public opinion to centralization in government is as great an obstacle as the Constitution itself. A single state can hardly be expected to take very high ground in regard to questions on which decisive action will mainly serve to retard its industrial development and drive capital and enterprise into other states. The difficulty is illustrated by the recent annulment of two attempts to regulate child labor on a national scale. Also our country is so large that effective labor organization on a national scale is practically impossible. An aggressive policy on the part of laborers themselves, if somewhat local in character, must tend to have the same effect as local political action.

The strike weapon effective only where a higher wage bill can be afforded

It would therefore appear that neither the weapon of the strike nor any direct attempt to raise wages at the expense of the employing class is capable of extorting large increases of wages. Such efforts can be permanently effectual only in industries that may be profitably carried on with a heavier wage bill than they now pay. Possibly there are many trades, large and small, which can do this. There is evidence that in many small manufacturing industries in this country in which conditions are worst, the addition to the payroll necessary to bring all workers up to a decent minimum standard would amount to a very small proportional addition to the total cost of the product. It would seem that this small loss to the employer could frequently be made up by improved organization, and perhaps would even be automatically compensated by the increased efficiency of a properly nourished and more self-respecting and contented labor force. In other cases the price of the article can be raised to the consumer and part of the burden shifted upon him, though this can be done only with commodities not subject to strong foreign competition and the demand for which is not too variable with changes in the price.

Industrial victory purchased at the expense of the poorest laborers

The gloomiest feature of the organization conflict between labor and capital is the danger that the gains which it does secure may be made at the expense of the lowest class of laborers. The skilled workers who are well organized and not readily replaceable may, by the strike or threat to strike, raise their own wages, already adequate for comfortable living, while the employer recoups himself by lowering or keeping down the wretched pay of the very class it is most important to help. It may be useful in understanding the situation to imagine, as theoretical economists are in the habit of doing, an ideal or frictionless state of things where every individual always knew his own best interest and always followed it.

We may safely say then that there is a theoretical competitive wage for every class of worker, which represents just what an employer would be able to pay and just what he would have to pay under such mechanically (not morally) ideal conditions. From this standpoint it is probably true that the higher paid workers get in general more than their true economic wages, what they are theoretically worth to their employers, while the lower classes get even less. It seems clear both from theoretical reasoning and from the study of historical facts that if the children of the workers of the lowest strata were left entirely to the care of their parents, there would be a dreadful acceleration in the decay of a large part of the vital strength of the nation. We may imagine the organization of labor extending much farther down than it does now, as in fact it seems to tend to work downward with the spread of education and the growth of industrial unrest. But there must remain a vast number of scattered, casual pickers-up of small jobs who, from the nature of their employments, will be unable to act together and make their power felt. The sufferings and the degradation of this class will be actually intensified by the very success of those above them in the struggle for better pay and better conditions of work.

Necessity of political action to save the children of the man farthest down

In the leading civilized countries it is coming to be realized that only the concerted action of the whole body of the people, that is, of the political state, can cope with the evil of the degradation of the children of poverty. Conflict of organized labor against the employers, even if it is successful, cannot alleviate — is more likely to accentuate — the danger to the social fabric from an inhumanly low standard of living among the poorest workers. We are getting rid, on the one hand, of the *laissez-faire* optimism of the founders of modern economic science, the easy-going belief that unobstructed competition is a panacea for all ills, that there is an invisible hand or higher harmony in the nature of things such that if every one

is left free to do as he pleases he must involuntarily subserve the best interests of all. On the other hand, we are getting rid also of the grimmer Darwinian optimism which contended that a stern process of elimination was necessary to the highest good of the race. We cannot even moralize about people's deserts or console ourselves with the argument that they have themselves to blame. Children are growing up in physical and moral surroundings which must make them a burden and a menace to the body politic, and effective action is the imperative demand.

There is nothing fundamentally new in this idea of subsidizing people to enable them to live. It is an ancient principle of English Common Law that very poor persons should be sustained by the rest of the nation. An English writer of the early fourteenth century states that the right to the necessities of life was in force before the Norman Conquest. Regularly administered relief out of taxation has been a fixed institution in England since the reign of Queen Elizabeth and was brought to this country by the early settlers. There are no adequate general statistics of poor relief in the United States, but it has been estimated that about one person in every twenty is helped by the state, either in institutions or through allowances.

It is doubtful, however, whether poor relief does much real, permanent good in the way of enabling people to lead normal human lives and to bring up their children according to a proper standard. Institutional relief may be set down as a mere palliative. It doubtless relieves much suffering in the case of the old or broken-down, but the lot of institutional children is perhaps as unfortunate on the whole as that of those in the poorest homes. Direct aid given to families to tide over periods of distress due to some temporary misfortune is subject to the fewest drawbacks. It is the constant endeavor of enlightened charity workers to bring it about that the largest possible share of relief shall be of this character. Moreover, it is often not so much gifts of money as intelligent, sympathetic advice and encouragement that are needed. There can be no greater mistake than to criticize public charities on the ground of a high ratio of administrative expense to the amount of pecuniary relief given. It is quite as often the best course to keep the money gifts as low as possible, provided the ministrations of the charity worker are what they should be. There are some grounds for regret in connection with the professionalization of this sort of service, and perhaps an ideal neighborhood life would make much of it unnecessary; but under the actual conditions obtaining in American cities with their varied and shifting population of workers, there seems to be no other practicable way of getting the work intelligently performed.

Laissez-faire certainly cannot apply to the children

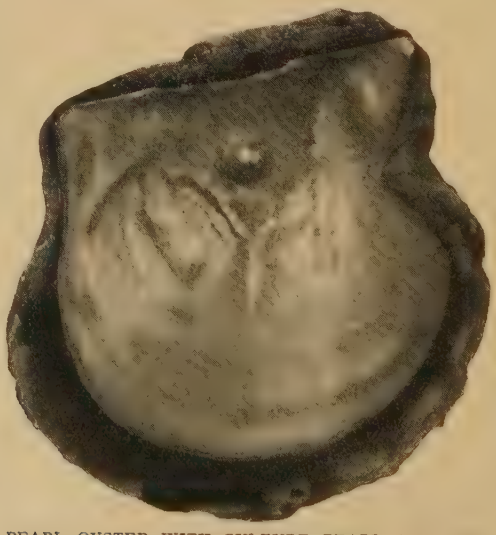
Both the *laissez-faire* economists and statesmen and the *laissez-faire* philosophers, such as Herbert Spencer, made one fatal mistake. If society were merely an aggregate of normal and healthy men, the unfettered competition for the good things of life might be an acceptable political ideal. But while society is organized on the basis of the family this system is impossible, since it would make the parents entirely responsible for the children, upon whom the future of society itself depends. Society cannot be indifferent to the cells of which its own future tissue is to be made, and it must treat the family as a unit. In America, in particular, this has long been recognized. The state has accepted the obligation of providing free for the poorest child the best education it can profit by. From educating children to guaranteeing them adequate nourishment is but a short step, and in many places it has already been taken. Indeed, the connection between the two was direct. The poor progress of the underfed slum children suggested the cause, and it was soon found that when they were given a cheap but nourishing lunch at school they did much better in their work. The most remarkable current development in this field is undoubtedly the progress of child labor legislation, which is often fought bitterly by the parents of the children to be benefited. Here again one problem leads to another.

The ultimate problem; the specter of Malthusianism

The children called out of the workshops must have opportunity for rational, healthful play, and educational opportunities that they can use and profit by. Thus the school system, in its upper reaches, is being transformed in the interest of the future citizen.

The main consideration which led the dominant school of writers two generations ago to believe in the futility of political action aimed at bettering the lot of poorest humanity was the doctrine of Malthusianism. This was the idea, at one time advocated by the English clergyman Malthus, that population always tends to increase up to the limits set by the food supply and constantly to press upon those limits. If this were true it is evident, as they argued, that alleviation could be but temporary, that when the pressure of misery was eased off a bit marriages would be earlier and families larger until the old wretched state of things was restored on a larger scale. In recent times this doctrine has been much modified. We know that there is a state in which it will hold true. Simply to give the poorest classes more food, or more money, would probably do more harm than good. But if as their conditions are improved ambition is aroused, and this will follow from free education and the right sort of material relief, the result will probably be just the opposite. Misery and immoderate multiplication are reciprocally cause and effect. At the present time, students of these problems are concerned not so much with the question of absolute pressure of population as with the selective effects of encouraging or discouraging the increase of various stocks. Where a stock is organically deficient, there is great danger lest in the effort to improve it the race as a whole will be injured. It would seem that a systematic endeavor to provide a civilized standard of living for all must be combined with a certain minimum of safeguards against racial deterioration as a result of that endeavor.

Thus the problem grows in complexity. As the relations of men multiply and become more complex the requisite social organization becomes more difficult to attain. And this is especially difficult in our own country, where the love of liberty has been exaggerated into a one-sided individualism, a dread of political power, and where historic forces have given us a political system with mainly negative ideals and where in consequence intelligent efficiency in public action meets with many obstructions. We have before us in its most acute form the great problem of the Anglo-Saxon peoples: to effect an adequate organization of society for social ends without sacrificing the liberty and personality of the individual. This great end cannot be achieved at a bound, but we must believe that patient effort will yield steady progress and that our civilization will ultimately be found equal to its task.



PEARL OYSTER WITH CULTURE PEARL ATTACHED

HARNESSING THE OYSTER

How the Succulent Bivalve is
Irritated into Creative Activity

THE CULTURE-PEARL INDUSTRY OF JAPAN

PERHAPS the peculiar fascination that the pearl has possessed for every age and race lies in the elusiveness of its charm. Try to describe it, words fail: seek the word's history, and it eludes and bewilders you in its oft-employed symbolism, "the pearl of great price", "the pearl among women", "pearls before swine". Attempt to visualize it, and moonshine, dewdrops, tears are the nearest one can get.

In the very earliest times, when men lived close to nature, it was believed that the pearl had its origin in a drop of dew. The Arabs have a legend that the pearl-oyster rose to the surface of the water in the early morning and drank the dew-drops, then with the breath of the air and the light of the sun brought forth lustrous pearls. In the first century Pliny writes, "The fruit of these shell-fishes are the pearles, better or worse, great or small according to the qualitie or quantitie of the dew which they received." And this origin of the pearl was very generally believed in Europe and the East up to the fifteenth and sixteenth centuries. There is an old German proverb which says, "Perlen bedeuten Tränen", and Titania's sprite

> "must go seek some dewdrops here
> And hang a pearl in every cowslip's ear."

But at the end of the fifteenth century, explorers of the Western World found the natives holding the opinion that pearls were those eggs of the oyster which were not cast forth but had stuck to the matrix, and were there fed unwillingly by the oyster. There was some confusion between these two beliefs up to the seventeenth century, when Reaumur first demonstrated that the pearl and the interior of the shell were of the same material. In the next century Linnæus claimed that pearls could be produced by piercing holes in the shell of the oyster with a fine auger, and in the small wound inserting an irritant, which in due course would be converted into a pearl. His secret was strictly guarded and the process lost after his death. Almost at the same time, we learn from some letters of a Jesuit missionary to China, Father d'Entrecolles, that this experiment had been tried by the Chinese as far back as the thirteenth century. This theory of Linnæus and the Chinese is one of the three commonly accepted for the formation of pearls in the pearl-oyster.

The oyster, a mollusc with a very soft body, is a luxurious creature that protects himself by lining his shell with a beautiful smooth material called "nacre" or "mother-of-pearl", and he extends this covering to any object coming in contact with his body. Thus, if a grain of sand, fragment of wood, or splinter of rock should penetrate his shell, he throws over it this smooth lustrous mantle which is his defense against irritants. Nacre is formed of thin irregular layers, overlapping one another with corrugated edges, and it is the breaking and reflection of rays of light upon these edges which give to the pearl its sheen, orient or luster. Without this luster the pearl does not rank as a gem-pearl; it is greater in the true pearl than in mother-of-pearl because the curvature of the surface is greater, and the layers necessarily smaller and more broken.

A second theory of pearl formation, adopted by recent scientists, is that the pearl is the covering of a parasitic worm which enters the mollusc in its larval stage, in its growth assumes a spherical form, and then dies. Then, as M. Raphael Dubois expresses it: "the ornament associated in all ages with beauty and riches is nothing but the brilliant sarcophagus of a worm." One more explanation there is: pearls may be muscle-pearls or enveloped gall-stones, found at or near the insertion of muscles.

ORIENTAL PEARLS

BUTTON PEARLS

SEED PEARLS

FOUR PAIRS OF TWINS

BAROQUES

PEAR- AND EGG-SHAPED

BIRDS' WINGS

All molluscs can and do produce pearls, but it is only in the so-called "oyster pearl" that certain of the essentials of the gem-pearl are found. It must have a fine orient, a perfect skin of delicate texture; a decided color whether it be white, pink, creamy gray, brown or black; and a symmetrical form, either perfectly round, pear drop, egg or button-shaped. Sometimes the pearls are double, triple or multiple, as in the case of the famous Southern Cross; sometimes they are elongated as those found in American rivers and near the hinge of the shell. These are called "hinge-pearls". The color has no connection with the luster; it is generally the same as that of the shell-nacre, black in black, pink in pink. The most common and most desirable is white or silvery. While the Ceylon pearls are usually white, those from American rivers are noted for their variety in shade.

From earliest times, the demand for pearls has been great, particularly in the East. The Japanese call the pearl one of "the seven costly things" (*Shippo* or *Nanatsu-no-takara*). Their price has fluctuated in the West according to the more fickle fashions prevailing there, but they have never at any time been without considerable value, and today rank among the most precious gems. There was the danger that the pearl fisheries might become exhausted, and efforts have been made to keep up the supply by artificial means.

One of the dreams of medieval alchemists was the creation of pearls. We possess two ancient Greek treatises, one of which tells how to clean true pearls, and the other how to make them artificially by a *tour-de-main* founded on the properties of chloride of mercury. In 1680 Jacquin, a rosary-maker of Paris, succeeded in making false pearls by encrusting molds with fish-silver. But the culture of the true pearl was first discovered by the Chinese. Ye-jin-yang, a native of Hoochow, in the thirteenth century started the industry by cultivating the river-mussel, and today near Teh-tsing it forms the staple occupation of several villages, employing as many as 5000 people. In Chung-kwano, the center of the pearl culture, a temple has been erected to the memory of the originator of the trade. Father d'Entrecolles writes an amusing letter in 1734, describing how the Chinese "put the mussels in fresh water where the dew fell, where no female could approach, nor barking of dogs nor crowing of chickens be heard". Small round pellets of the size of a pea, formed of pulverized seed pearls moistened with holly juice, were inserted into the valves and the mussels put back into the water for a certain time and fed.

Later the shells were again opened and the pearls extracted. However, the best of these Chinese pearls are of inferior quality and valuable only as curios.

No greater result was achieved by Linnæus in Europe, though the incentive of his experiments was not lost. Similar attempts have been made in the United States, the Ceylon fisheries, in Saxony, Sweden, Finland, and in Japan. Dr. Louis Bouton in 1897 succeeded in producing pearls in the abalone, this being a very hardy species for experimental purposes. He was so successful that it is probable that some day there will be a profitable business in growing pearls in abalones on the Pacific Coast of the United States. Mr. Vane Simmonds of Cedar Rapids, Iowa, experimented in a way calculated to save the strain on the oyster's muscles, and thus produce a healthier pearl. He caused the oyster to open under the influence of air and sunshine, then inserted a small wooden wedge and immediately immersed the oyster to revive it. After a few minutes the mantle was raised, a pellet of wax put in and the mantle slipped back as the creature was returned to the water.

BLISTER PEARL WITH CRAB INSIDE

BLISTER PEARL SAWN OFF TO SHOW A BIVALVED SHELL INSIDE

BLISTER PEARL WITH MUD INSIDE

BLISTER PEARL SPLIT OFF TO SHOW CRAB INSIDE

CURIOUS FORMATION OF AN ABALONE PEARL

To a Japanese, however, belongs the glory of achievement in the culture pearl. Mr. Kokichi Mikimoto of Toba, in the province of Shima, realized that the valuable Japanese pearl fisheries were being exhausted and began to cultivate the oyster. He exhibited some specimens of pearl oysters in the third National Industrial Exhibition of Tokyo, and there with Dr. Mitsukuri, professor of zoölogy in the Imperial University, first conceived the idea of cultivating pearl oysters for the production of pearls by the use of the right stimuli. Like most discoverers and inventors ahead of their age, Mikimoto had the usual disappointments, difficulties and failures, accentuated in his case by the unbelief and ridicule of his friends. He persevered, however, through eight long years, changing his methods a little, shifting his experiments, and at last believed he was justified in putting out a trial crop. It proved encouraging and he tried another and another, each time gaining ground in his quest of the pearl of great price, until now he produces culture pearls on a commercial scale.

Just out of the sweep of the great Gulf Stream, though near enough to feel its warmth, lies the sheltered Bay of Ago, a quiet body of water 12 miles wide, 6 miles long and 10 fathoms deep. This was the field chosen by Mikimoto for his enterprise, and he first leased the sea-bottom around the island of Tatoku. As the work prospered he increased the farm, until now it comprises some 50 nautical miles. The people employed in the fishery — several hundreds of them — make their homes on the island. Women do the diving, for they can remain submerged longer than men. Girls begin when they are fourteen years old, and become most valuable divers between the ages of 25 and 35. No greater contrast to the armored diver of aquarium and pictured adventure could be presented than the white-clad "sea-girls" of the Bay of Ago.

The sea girls wear a simple costume of white cotton knickerbockers, short skirt and blouse. Their long black hair is twisted up into a tight knob on top of the head, and a white cloth drawn over it. Special diving glasses to protect the eyes from the salt water are worn, but beyond these no other protection. Suspended from the waist of each woman is a small tub, into which she throws the oysters, which are later tipped into the boat. No weights are used as in the Persian Gulf and Ceylon fisheries; here they sink to the bottom, where they remain from 60 to 80 seconds.

MR. KOKICHI MIKIMOTO
The first to make a commercial success of culture pearls.

Work generally begins by sunrise, when the divers are taken out to the beds in large flat-bottomed boats, and landed on rocky projections from which, if the water is deep enough, they take their plunge. They utter curious hoarse whistling sounds both as they sink and come up. It is an exhausting occupation so the hours can not be very long; six to eight is the maximum. Most of the diving is done between March and December, as the sea is too cold in January and February. Wages run from 50 sen to 2 yen ($1.00) a day. An experienced worker can bring up 10 oysters from 10 fathoms in 60 seconds.

The methods of pearl culture as worked out by Mikimoto are easy to follow. The pearl oysters found in the Bay of Ago belong to the species *Margaritifera martensii*, which is rather small in size with a thin shell.

They are found at a depth not greater than 10 fathoms, anchored to rocks, stones and stems of sea-weed by a thread which the animal secretes. They live for about 12 or 13 years only. In July and August, the workers place small pieces of rock and stone in shallow waters where oyster larvæ abound. Very soon small oyster spats become attached to them, and these with their anchoring rocks are moved to deeper waters, where they can be kept warm during the winter months. After three years the oyster is sufficiently strong and grown to be brought to land and operated upon. The shells are opened, and small pearls or round fragments of nacre put in, to form the stimuli round which the oyster will build the pearl. Then the shells are put back in the oyster-bed, each being allowed a square foot of space.

For four long years, they lie undisturbed by man, but as subject to loss as the Argosies of old into which the Venetians put all their fortunes. The octopus and the star-fish prey upon young oysters: the "red current" *akashiwo*, or plague of microscopic organisms fatal to marine creatures, often sweeps through these waters; the choking sea-weed *mirumo* grows fast to smother them; the nuclei wash out. All these and many other evils are incident to the life of the oyster, or the growth of the pearl. At the end of the four years the divers bring up the shells, which reveal 5 to 7 pearls of marketable value in every 100 opened oysters. They are generally attached to the inner surface of the shell and have to be cut out, when they exhibit the essentials of true Oriental pearls in luster, texture and color. For some years the culture pearl grew only like a button, but in 1905 Mr. Mikimoto solved the problem of the round pearl, which gained a medal in the Tokyo Exhibition in 1914.

"The pearls possess in a marked degree all the features of the finest natural gems, with the enchanting satiny luster, and the tender iridescent rose and faint blue sheen aimed at but never attained by the makers of imitations. The shifting play of these exquisitely delicate tints is much like that of a faultless opal, which sends a deep flame from its heart rather than from its surface,"

RECOVERING THE OYSTERS ON THE "FARM"

WOMEN PEARL DIVERS IN THE BAY OF AGO

THE "SEA-GIRLS"

The pearl oysters are recovered from the bottom by women divers, their only mechanical equipment a pair of goggles. One is shown, ready to dive, on page 1760. The best divers are from 25 to 35 years old, having begun their training at 14. They can remain submerged from 60 to 80 seconds.

MONUMENT TO A GREAT EXPLORER

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HENRY HUDSON MONUMENT AT RIVERDALE, N. Y.

Overlooking the river that he discovered and that bears his name.

EXPLORERS IV

SIR HUMPHREY GILBERT — WHO PLANTED THE FIRST ENGLISH COLONY HERE
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SIR HUMPHREY GILBERT

Who Planted the First English Colony in America

SIR HUMPHREY GILBERT, first of the British empire-builders, was born at Compton, near Dartmouth, about 1539. Sir Walter Raleigh was his half-brother, Mrs. Gilbert marrying again on the death of Humphrey's father. Humphrey was thirteen years older than Walter; and it was from the older boy, who showed in youth a passion for the study of navigation, that the founder of Virginia and the discoverer of Guiana received the inspiration for his great achievements. The early part of Sir Humphrey's career was spent in fighting in France, Ireland and the Netherlands, and he won the honor of knighthood and the governorship of Munster.

But his interest in maritime discovery was greater than his taste for land warfare. He studied map-making, and invented a spherical instrument with a compass of variation, as a more exact means of navigation than the ordinary sea cards then used by sailors; and at twenty-seven he presented to Queen Elizabeth a plan for exploring the North West Passage to China. He was then too useful in Ireland for the queen to spare him, but his idea led to Frobisher undertaking the adventure. The latter's first successful voyage inspired the queen and her ministers with more confidence in Sir Humphrey Gilbert's skill in maritime discovery, and in 1578 he was granted letters patent for planting an English colony in America. Sir Humphrey sank all his fortune in the enterprise, and induced a large number of gentlemen adventurers to join him. But when the fleet put to sea, in 1578, quarrels broke out among the volunteers, each ambitious of power; they were struck by a tempest and attacked by the Spaniards. A fine ship was lost, and everybody disheartened, and Gilbert returned home a ruined man.

His letters patent only ran for six years. He was resolved to found an American colony before his powers expired. He raised some money by assigning some of his colonizing rights in Canada, and collected another body of adventurers, and even emptied some jails in order to get settlers for his new land. At last, on June 11, 1583, he sailed from Plymouth with 260 men and five ships — the *Delight*, *Golden Hind*, *Swallow*, *Squirrel* and the bark *Raleigh*, the last provided by Sir Walter Raleigh, who sailed on her, but shortly pleaded that sickness had broken out on his ship, and returned with her to England. Perhaps he did not like playing a subordinate part in the enterprise, for the next year he fitted out a fleet himself, and took possession of Virginia.

At the end of seven weeks, Sir Humphrey, with the other four ships, arrived at Newfoundland, and, finding the soil of the country fertile and well wooded, he decided to plant his first colony there. The English cod-fishers were already the strongest power at the Banks, and they welcomed the colonists and feasted them continually.

DR. DEE, FROBISHER AND SIR HUMPHREY GILBERT DISCUSSING THE NORTH WEST PASSAGE WITH SIR FRANCIS WALSINGHAM

But the jailbirds that Gilbert had brought with him soon began to misconduct themselves. They plundered a fishing-bark, and then fled to the woods and plotted to steal some of the ships. In the meantime, Gilbert set out with three of the ships on a voyage of exploration to Nova Scotia, but his largest ship was wrecked off Cape Breton. Bad weather and troubles with the criminal party of his men were more than he at last could cope with. "Be content; we have seen enough!" he exclaimed. "I will set you forth royally next spring, if God sends us safe home!" But he never reached home. Sailing with two of his ships back to England, he was caught in a storm off the Azores on September 9, 1583, and his small vessel went down with all hands.

CHARLES FRANCIS HALL
An American Pioneer Arctic Explorer

CHARLES FRANCIS HALL, an American pioneer Arctic explorer, was born at Rochester, New Hampshire, in 1821, and received his education at the common school and academy of that town. He was successively blacksmith, journalist and stationer, but his interest becoming aroused in the fate of Sir John Franklin, he decided to aid in the search for that distinguished British explorer.

Sir Francis Leopold McClintock, who had headed one of the various relief expeditions, published in 1859 a record which seemed to demonstrate that Franklin and his party had perished, but this did not seem conclusive to Hall, who tenaciously clung to the idea that at least some of the party must be alive, and he determined to find them or at least make certain of their fate. He was able to arouse the interest of Henry Grinnell, a wealthy New York merchant, and through his assistance and public subscriptions, he was enabled on May 29, 1860, to sail from New London on the whaler *George Henry*, commanded by S. O. Buddington (1823–1888).

The expedition was bound for Cumberland Gulf and Hall spent two years in the Arctic, having no special outfit beyond his own boats, sledges and supplies. While he was unsuccessful as to his main purpose he lived for two years among the Esquimos, near Frobisher Bay, and learned about their life and habits. He discovered relics of Sir Martin Frobisher's expedition, 1577–1578, including a stone house.

After his return in 1862, on account of the Civil War, he was unable to secure the support for a second expedition, but in 1864 he published an interesting volume entitled "Arctic Researches and Life among the Esquimaux" which supplied him with funds so that on July 1, with a poorly equipped party, he was able to leave again for the north and in the following August was landed on Depot Island, 64° N. 90° W., with his boat and provisions. Again he made himself at home with the Esquimos and spent five years there. In 1866, at Cape Weynton, south of Boothia Felix, he encountered Esquimos from whom he obtained relics of the Franklin expedition in the form of silver forks and spoons bearing Franklin's crest, and other articles. These were found on the line of retreat of the Franklin party which Hall was able to follow. In May, 1869, he reached the southeastern coast of King William Land, and assured himself by conferences with the natives of this region that 79 of Franklin's men had perished of starvation in King William Land, while probably the remaining 26 had reached the mainland only to die.

Among his geographical explorations during this trip was the very valuable work of filling the gap between the farthest north route of Rae, in 1846, and Parry's farthest north in Fury Strait, reached in 1825, which completed the mapping of the north coast of the American continent.

In this year, 1869, Hall returned to the United States and the record of his achievements was so interesting and impressive that Congress authorized "an expedition to the North Pole" with an appropriation of $50,000. The *Polaris*, a small naval vessel, was fitted out and sailed from New London, July 7, 1871, with Hall in command. The United States ship *Congress* accompanied the expedition as tender and proceeded with it as far as Godhaven, Greenland. With a sea unusually free of ice Hall and the *Polaris* passed through Smith Sound into Kane Sea and thence through Kennedy and Robeson Channels to the Polar Sea, where on August 29, 1871, the *Polaris* was in latitude 82° 11′ N., the highest point at that time ever attained by any vessel.

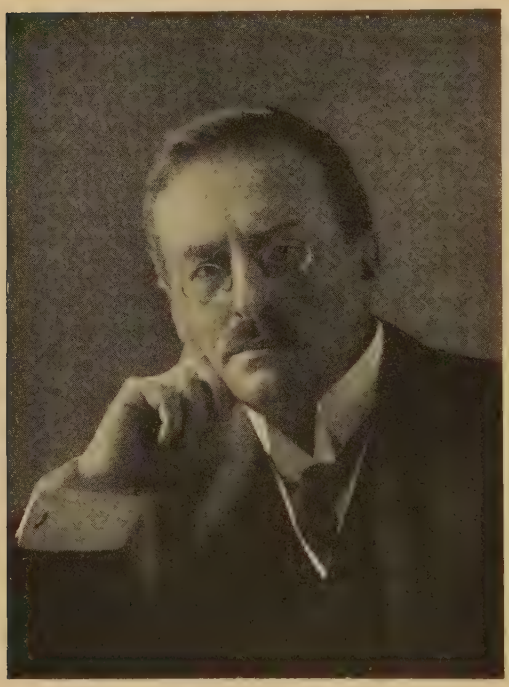
Hall and his party went into winter quarters at Thank God Harbor, Greenland, 81° 38′ N., and from this base made a sledge journey of two weeks, October 10–24, north to Cape Brevoort. He discovered the land on the west side of Robeson Channel and noted that it extended approximately to Cape Joseph Henry, 82° 48′ N., naming the cape after the distinguished secretary of the Smithsonian Institution at Washington, and being the first to see the land on the west side of Robeson Channel, north of Cape Brevoort.

This trip Hall survived but a short time, dying on November 8, 1871. He was buried near his base in a grave over which the British polar expedition of 1876 placed the significant epitaph, "Who sacrificed his life in the advancement of science". While Hall was not a trained scientific observer, but rather an enthusiastic explorer, nevertheless his death ended the chance for subsequent geographical work by the expedition. After a strenuous winter the *Polaris* left Thank God Harbor August 13, 1872, and being caught in the ice pack in Kennedy Channel, drifted southerly with the pack until on October 13, near Littleton Island, she was so bitterly nipped during a gale that preparations were made to abandon her. A part of the crew were caught in the ice floe and drifted nearly 2000 miles, to be rescued by the sealer *Tigress* off the coast of Labrador. In the meantime, Captain Buddington, the sailing master, had beached the leaky and damaged *Polaris* near Lifeboat Cove, where a house was built of the timbers of the vessel for the winter. In the spring of 1873 two small boats were built in which the party set out for Upernavik, and after a trip of about 200 miles the survivors were picked up near Cape York by the Scotch whaler *Ravenscraig*.

While this expedition was unfortunate, not only in the death of Hall, but in its other mishaps, yet its geographic and scientific results were important. Hall was a man of indomitable will, resourceful and patient, and for a man not trained as a scientist or explorer his accomplishments were really wonderful. In addition to unstinted praise from British and French

explorers he received, posthumously, the Roquette Medal, from the Société de Geographie of Paris. His exploration of the Greenland and Kennedy Channels, the discovery of Hall Basin and Robeson Channel, the determination of the extent of Grinnell Land and Greenland some two degrees of latitude northward, and his discovery of the unknown frozen Polar Sea were achievements which placed his name in the forefront of American explorers.

SVEN ANDERS HEDIN
Explorer of the Desert of Central Asia



SIR SVEN HEDIN

SVEN ANDERS HEDIN, one of the greatest Asiatic explorers, was born in Stockholm in 1865, the son of a Swedish architect. Educated in his native city and at the chief university of his country, Upsala, he began his life's adventure at twenty by wandering through Mesopotamia and Persia. In 1890 he was a member of an embassy sent by King Oscar to the shah of Persia, and he profited by this occasion for studying further the languages of Asia. Thus he made a journey through Khorasan and Turkestan, going as far as Kashgar to ascertain if it would serve as a base of operations for the exploring of the heart of Asia, on which he had long set his mind. His interest in Persia was so aroused that he returned to it later overland from the Black Sea, and made a most useful journey through the salt deserts to the eastward of Teheran, and so by way of the River Helmund and Beluchistan reached India. During the journey he traced in part the historic route of Marco Polo through Persia.

Hedin devoted all his youth and early manhood to the task of preparing himself for his great adventure. He learned to draw, to climb, to sail, to use all the scientific instruments in any way helpful to him; and in spite of his intense study he kept himself as fit as an athlete training for a long race. For several years he studied the geography of Central Asia, partly at home, and partly at the University of Berlin, under Baron von Richthofen, a first-rate geologist, as well as a geographer who had won fame by his scientific exploration of China in 1860 and 1868–72. Setting out from Stockholm on October 16, 1893, Hedin traveled by steamer and rail to Orenburg as his starting point. He returned to Stockholm, by way of Peking, on May 10, 1897.

Between these dates he had crossed in two directions the most terrible desert in the world, the Takla-makan; he had explored unknown regions in northern Tibet, and made three excursions in the Pamirs; he had cleared up the mystery of a strange desert lake, Lop-nor, mentioned by Marco Polo, and had generally drawn back the curtains of darkness that covered a large part of Central Asia. Danger had taken many different forms but none had been able to deter Hedin. He had mapped out thousands of miles, investigated the geology of unknown regions, studied the winds, moisture and temperature on plains and mountains and wildernesses, had mixed on friendly terms with unknown tribes, learned their customs, measured their heads, photographed them and studied their religions and languages. He had also collected plants, had examined the ruins of ancient civilizations, had estimated the volume, speed and depth of the strange rivers that lost themselves in deserts where the wild horse and the wild camel still range at large.

Written in an uncommon and vivid style, the tale of his travels in "Through Asia" (1899) at once became one of the classics of exploration and has been translated into twelve languages.

In 1899 he returned to the desert, where he had so nearly perished, and surveyed the great River Tarim, that flows along the edge of the wilderness, to sink at last in the sands. He then went on to Tibet, and returned to Europe in 1902. Four years later, the passion for adventure again led him into the unknown regions of the world. He went overland to India, intending to cross the frontier and explore Tibet, but the British authorities could not permit him to do so. So he set out from Kashmir, ostensibly for Turkestan, but suddenly turned into the forbidden land. The Tibetans tried to force him to retrace his path, but he succeeded in exploring the southern part of the country, and interviewing the Tashi Lama, and investigating the hitherto unvisited sources of the Brahmaputra by 1907.

Ennobled by the king of Sweden in 1897, Sven Hedin was elected a member of the Paris Academy of Sciences in 1911, and traveled at the front as a guest of the German army during the Great War ("With the German Armies in the West", 1915; "The War against Russia", 1915). His "From Pole to Pole" (1911) has been translated into fourteen languages, and he received honorary degrees and medals from many universities, including Oxford and Cambridge, and learned societies. In 1921 he finished the publication of "Southern Tibet", a monumental work in 8 volumes of text and 2 of atlas.

HENRY HUDSON

An Elizabethan in Quest of the North Pole

HENRY HUDSON, the great Elizabethan navigator, was possibly the son of a London alderman. But all that is known certainly about his early life is that he was a citizen of London, had a house there, and was brought up in the service of the Muscovy Company. He emerges into the clear light of history in the spring of 1607, when he fitted out a vessel called the *Hopeful*, and set forth from Greenwich on May 1 to discover a passage to China across the North Pole. Hudson was not unaware of the perils and difficulties of such a voyage, for the result of Barentz's fatal attempt was known to him, and he had studied the best charts of his age. Yet with a crew of eleven men and a boy, in a craft about the size of the smallest whaling vessel, he aimed at sailing right across the Pole to Japan; and as an actual achievement in polar exploration he succeeded in making as careful a trial of the possibilities of this extraordinary voyage as has ever been done in modern times.

Taking his little son with him on the voyage, he sighted the east coast of Greenland on June 13, 1607, and continued along a northerly course for nine days. In so doing he discovered a large stretch of new land, that he named "Hold With Hope". Then, steering northeasterly along the edge of the pack-ice, he came to Spitzbergen, and discovered more new land there. Turning back, he attempted the feat of sailing round the unknown north end of Greenland, and returning to England by Davis Strait, but the ice blocked him. After discovering a lonely island that is now improperly named Jan Mayen, after a Dutch skipper who saw it some years later, Hudson returned safely to the Thames on September 15, 1607. Both from a geographical and a commercial point of view his voyage was important. He reached almost as high a latitude as Scoresby did two hundred years afterwards; he discovered new lands in Greenland and Spitzbergen; and he was able to bring to the Muscovy Company news of a great whale-fishery that was richly exploited for two hundred years thereafter.

It was no doubt owing largely to this practical success that Hudson was provided the following year with the means of fitting out a second expedition. He sailed from the Thames on April 22, 1608, and reached the coast of Nova Zembla on June 26. But he found the ice barrier impenetrable by his small craft. After examining the coast of the wild Arctic island where Barentz had perished in a similar attempt to sail round Siberia to China, he turned his vessel southward, and arrived in England on August 26, 1608.

THE LAST VOYAGE OF HENRY HUDSON — FROM A PAINTING BY THE HON. JOHN COLLIER

As there were no commercial results from his second polar voyage, the Muscovy Company declined to finance a third expedition. So Hudson entered the service of the Dutch East India Company, and received in 1609 the command of a vessel of 80 tons, the *Half Moon*, in which he intended to follow the track of Barentz, and further extend the exploration of the Siberian route. But when he reached the Arctic seas his crew of only 18 or 20 men were disheartened by the cold and ice, and threatened to mutiny if Hudson did not turn back. They were, in fact, already in open rebellion, and Hudson was compelled to listen to them.

In order to pacify the mutineers, he proposed to them to seek for a passage to China through Davis Strait, and with some trouble he got them to agree to this course. He landed on the American coast, replaced his foremast, which had been broken in a storm, and profited by the occasion to start trading in furs with the natives, but his

undisciplined sailors made the natives angry by their exactions, and Hudson was compelled to set sail. He continued to follow the coast northward, and on September 12 reached Sandy Hook. He spent a month exploring the river named after him, ascending as high as the present site of Albany, but his provisions began to run short, and his mutinous crew compelled him to return to Europe. He reached England on November 7.

In the following year, 1610, Hudson tried to renew his engagement with the Dutch East India Company, but the terms they offered were so poor that the famous navigator again approached the English company. His old masters were willing to fit out a ship for him, and he sailed in April and by June 10 had reached Hudson's Strait, passing into the bay beyond (Hudson's Bay), and spending some months examining its coasts and islands.

In September one of his officers tried to excite revolt against his rule. Hudson was compelled to strip him of his rank, but this act of justice only exasperated the sailors. In the early part of November, Hudson reached the extremity of the bay named after him, fixed on a spot to winter in, and drew his ship up on dry land; for though he had left England with only six months' provision, he was resolved to face the Arctic winter rather than give up the search for the North West Passage. Happily, his crew were able to kill a great number of birds, and so, though their rations were scanty, they did not have a very distressing winter. But when spring came and the ice cleared away, and Hudson prepared to sail his ship, he found that the sailors were resolved to get rid of him. Undisturbed by the conspiracy, the brave navigator distributed to each man his share of biscuit and paid each the wages due, and waited for the outcome of the successful conspiracy. He had not long to wait. The crew seized their captain, his son, and seven men who took his part, put them on board a boat without arms, provisions, or instruments, and set them adrift on June 23, 1611. Some few of the murderers survived the return voyage to England, but do not seem to have been punished for the crime.

LOUIS JOLIET

An Early Explorer of the Mississippi Valley

LOUIS JOLIET, a Canadian discoverer and one of the first explorers of the Mississippi Valley, was born at Quebec, December 21, 1645. While there is a dispute as to whether he, Marquette or La Salle should be given the honor of being the first to explore the Mississippi, he was, however, among the foremost of the Canadian pioneers to penetrate to the great West, and to realize its extent and possibilities. He was the son of a wagon maker and was educated for the priesthood in the Jesuit College at Quebec, but after taking minor orders in 1662, he subsequently abandoned his plan to become a priest. In this he was in large part influenced by his innate fondness for adventure and the woods, and early he became known as an intrepid voyager. His first important expedition was in 1669, when he went with a party to search for copper on the shores of Lake Superior as well as to find a more direct route from Montreal to the upper lakes. On this trip Sault Ste. Marie was reached and much new country was seen, exploration being made of the shores of Lake Superior. In 1671 he was one of the party with Saint-Lusson at Sault Ste. Marie which took possession of the country around Lakes Huron and Superior in the name of King Louis XIV of France and made a treaty of friendship with the Indians. At this time the French government was greatly interested in exploration to the West, and in 1671 Joliet was selected by Frontenac, then governor of Canada, on the advice of the intendant Talon to visit the West and to explore the course of the Mississippi which was supposed, then, to flow into the "Sea of California" to the west.

Joliet reached Mackinac in December, 1672, and there found Father James Marquette, who had been anxious to visit the territory of the Illinois to the west and south. Here he remained during that winter, spending the time in active preparations, and especially in securing data and maps from the Indians as to the country to the west and south.

Arrangements were made to continue active exploration in the spring. Joliet and Père Marquette, with five other Frenchmen, in two birch-bark canoes, paddled up the Fox River until they reached a short portage where they carried over to the Wisconsin River. Proceeding down this stream they entered the Mississippi on June 17, 1673, near the present site of Prairie du Chien and passed down its waters by where the Missouri and Ohio joined it, as far as its junction with the Arkansas. Progress to this point and the information they secured from the Indians they met was sufficient to prove to them that the Mississippi River did not flow westerly into the Pacific Ocean but emptied into the Gulf of Mexico, but that there was a route to the Gulf of California and that some of the natives even went as far to trade. With this very satisfactory information they turned north, retracing their steps up the Mississippi but left it to follow up the Illinois River and then into the Desplaines and finally by the Chicago Portage to Lake Michigan on the way to Quebec. Returning to Green Bay after paddling some 2500 miles, Joliet then proceeded to Sault Ste. Marie. Unfortunately on this return trip Joliet's canoe was capsized in the Lachine Rapids, and all of his maps and other papers lost. Nevertheless he was able to redraw many of his maps from memory.

In the spring of 1674 Joliet went to the north, reaching the Mission of St. Francis on Lake Winnipeg in September, and passing the winter there. On his return to Quebec he sought to arouse the interest of the French government in the rich lands of the Mississippi Valley and called attention to the vast mineral resources which were apparent on the journey, but his plans and advice for the colonization of the newly discovered territory were, at the time, rejected. However, about 1680 he was presented with the Island of Anticosti, where he built a fort. Later he explored Labrador and in 1693 was appointed royal hydrographer. To him was granted the seigniory of Joliet, south of Quebec, on April 30th, 1697, which remained in possession of his descendants for many years.

Joliet died in Canada in May, 1700.

ELISHA KENT KANE

Surgeon and Organizer of Systematic Arctic Research

ELISHA KENT KANE, the first of a distinguished group of American Arctic explorers, was born in Philadelphia, February 20, 1820. It seems strange to realize that one who endured the rigors of the Arctic climate was forced to leave the University of Virginia on account of ill health, but later, able to resume his studies, he was graduated in medicine at the head of his class at the University of Pennsylvania, in 1842. In the following year he was appointed assistant surgeon in the United States Navy, serving on the China station and on the coast of Africa, as well as legation surgeon at Peking and in private practice in China. He also served during the Mexican War, where he was wounded while on special service, and later was on coast survey duty in the Gulf of Mexico. From this detail he was relieved at his own request for duty with the first Grinnell Arctic expedition, which then was being organized. Kane's service with the Navy had accentuated his fondness for travel, exploration and adventure, and he often left his ship to penetrate into the interior of the Philippines, Egypt or Dahomey.

In the first Grinnell expedition, which was sent out in May, 1850, to search for Sir John Franklin, Dr. Kane was surgeon of the *Advance*, one of the two American ships (the other was the *Rescue*), purchased and strengthened for Arctic service through the liberality of Henry Grinnell, of New York, and accepted by Congress on May 5, 1850. In connection with eight English ships they searched the region of Lancaster Sound but failed to get an advantageous point for further activity and it was decided to return to the United States. In the meantime an island north of Cornwallis Island, to which the name of Grinnell Land was given, was discovered, but this was not the more important Grinnell Land which bordered on the Frozen Sea. On the return of the expedition the two ships were caught in the ice in Wellington Channel and for eight months drifted southeasterly into Baffin's Bay, where in June, 1851, they finally escaped from the pack.

In the meantime his interest was aroused in Arctic research and he endeavored to enlist the aid and coöperation of a number of people in a scientifically planned polar expedition. Furthermore, Lady Franklin asked him to undertake a search for Franklin and his companions. Again the generous Henry Grinnell and George Peabody placed resources at his command and Dr. Kane sailed northward May 30, 1853, in command of the brig *Advance*. On this expedition Dr. Kane was accompanied by Dr. Isaac I. Hayes as surgeon, and it was proposed not only to make a search for Franklin and his companions, going overland from Baffin's Bay to the shores of the Polar Sea, but to extend northward the work of earlier explorers in the Smith Sound region. The *Advance* reached Greenland and enlisted a number of Eskimo recruits which were taken aboard, and then followed the coast of Smith Sound, achieving a point 78° 43′ N., which was the highest latitude attained by a sailing vessel. As further progress was impossible, winter quarters were established at Van Renssaeler Harbor from which exploring parties set out by sledge. One of these discovered the Humboldt Glacier, 79° 12′ N., which was found to extend northerly many miles. In the spring of 1854 an attempt was made to push northward but the early attempts were not particularly successful. Two lives were lost and two other members of the party were hurt, while others suffered from disease. In the meantime other explorations were carried on and a dog sled expedition reached Cape Constitution, 80° 35′ N., in June. From this point Kennedy Channel was seen to be open and Dr. Hayes with a dog sled crossed Kane Sea and reached Cape Forks in Grinnell Land proceeding further to the north near Cape Frazier at a latitude of 79° 45′ N. In July, as the ice was unbroken, Dr. Kane tried to reach Beachey Island 400 miles distant to secure assistance, and later in the year half of the party under Peterson, a Dane, abandoned Dr. Kane and the ship in an attempt to reach Upernavik. After three months of hardships they were forced to return.

In May, 1855, it was decided to abandon the *Advance* which was frozen hard in the ice and Dr. Kane moved his boats and sick to the open sea, a distance of some 60 miles, with a loss of one man on the journey. During this trip he received much kindness and assistance from the Etah Eskimos and arrived at Cape York July 21, 1855. Crossing Melville Bay he reached Upernavik August 6th, after a boat journey of some 1200 miles. Here they were picked up by a United States squadron sent for the rescue of the party.

Dr. Kane's expedition was one of the first exploring parties systematically organized and equipped that had gone to the Arctic up to this time, and the scientific results were proportionately large. It obtained a greater knowledge of the Etah Eskimos and of the most northern lands of that day. The scientific observations were more accurate, systematic and generally more valuable than those of any preceding polar expedition. The return of the party aroused great enthusiasm and furthered interest in polar explorations. A medal was conferred on Dr. Kane by the United States Congress, while he also received the Founders Medal of the Royal Geographical Society in 1856, and the gold medal of the *Société de Geographie*. Unfortunately Kane's experiences in the north had impaired his health and he died in Havana, February 16, 1857.

RENÉ ROBERT CAVELIER, SIEUR DE LA SALLE

Leader of Many Expeditions of Brilliant Discovery

RENÉ ROBERT CAVELIER, SIEUR DE LA SALLE, a French explorer, famous for his discovery of the Ohio River and his exploration of the Mississippi and other regions of the West, was born at Rouen, France, November 22, 1643. He was a member of a wealthy family but lost his inheritance by becoming a Jesuit novice, though later he forsook this calling and at the age of 24 emigrated to Canada, where he had a brother who was a member of the Sulpician Order. He was granted by the Superior of the Seminary of St. Sulpice a large tract of land near Montreal, afterwards known as Lachine, on account of his subsequent schemes to reach China across the American continent.

In 1669 La Salle, after numerous short trips and conferences with the Indians, became interested in exploration and was granted authority by the Comte de Frontenac, governor of New France, to make an extensive tour of the unknown regions to the west. To obtain the necessary funds La Salle sold his seigniory and, with four canoes and 14 white men, set out, accompanied by another expedition under Dollier de Casson, which was organized at the seminary for the conversion of the Indians of the upper lakes, and which included two Sulpician priests.

In all seven canoes and 24 men made up the party which started up the St. Lawrence River July 6, 1669. Their course lay through Lake Ontario, at the west end of which between the Grand River and the head of Burlington Bay they encountered Joliet from whom they obtained a map of the northern lakes and of his general exploration in the western field. On the basis of Joliet's statement as to the lack of religion prevailing among the Indians of the north de Casson proceeded in that direction to establish missions, while his account of the vast rivers led La Salle to turn to the south and west. Accordingly La Salle devoted the next two years independently to exploration of which but vague and unauthentic records remain, as his maps and records have not been available since 1756. In the main, however, it is known that he turned to the south of Lake Erie and descended a branch of the Ohio, reaching that river and following it at least to the Louisville Rapids, and possibly to its junction with the Mississippi. Here he was deserted by his men and forced to return alone to Lake Erie.

A second expedition organized by the explorer went up the Detroit River to Lake Huron, whence it passed into Lake Michigan and crossed the Ohio Portage to the Illinois River. But scant record is available of this expedition and it may have been that on this trip La Salle reached the Mississippi. Had he done this he would have anticipated both Marquette and Joliet, but there is no positive evidence to that effect, and the matter of the actual discovery has always remained unsettled.

La Salle, however, had seen enough of the West to arouse his visions of empire and to recognize as well its possibilities of wealth in the way of fur and other resources, so he returned to Montreal before 1673 to lay before the Comte de Frontenac his plan of following the Mississippi to its mouth and developing the entire region so far as possible. The governor had recommended La Salle for a patent of nobility and a tract of adjacent land near Fort Frontenac (now Kingston) on Lake Ontario, where July 18, 1673, he was placed in command of the post that had been established.

This was indeed a particularly valuable location as regards trading with the Indians, and had traffic been the explorer's sole object he should have been fully satisfied. However, his thoughts were on the West and he was able to arouse the interest of Frontenac in his various projects so that with the governor's approval La Salle went to France in 1674 to submit to the court petitions for substantial aid and patents for lands that might be discovered. He was granted conditional assistance towards carrying out his explorations and development and returned to Canada for a second time in 1677. He brought with him 30 men and complete equipment, secured almost entirely by his own efforts, but most important royal letters patent, granting him the right to pursue further explorations at his own cost on condition that they should be completed within five years. These grants included the right to build forts, the monopoly of trade in buffalo skins, as well as seigniory over such lands as he might discover.

On his return to Canada La Salle was accompanied by the Chevalier Tonty, who was a loyal friend and an able lieutenant to him in his subsequent expeditions, while awaiting him at Quebec was a Belgian friar, the Franciscan Louis Hennepin, who became quite as famous as an explorer as a missionary. La Salle's new powers and privileges aroused jealousy on the part of other traders and settlers in Canada, but he proceeded with the organization of the expedition which in November, 1678, sailed from Fort Frontenac on Lake Ontario.

The ship *Griffin* was built for the expedition above Niagara Falls on Lake Erie, and in her La Salle and crew on August 7, 1679, set sail, the intervening time having been occupied by a number of small expeditions conducted with incidental losses. The party proceeded as far as Green Bay, on Lake Michigan, where a cargo of furs was secured and sent back, but the ill-fated *Griffin* was never heard from. La Salle now turned his attention to exploration and with 4 canoes and 14 men explored the western shores of Lake Michigan, while Tonty with 20 men devoted himself to the eastern. The junction of the two leaders took place at the mouth of the Miami or St. Joseph River and Fort Miami was built. Leaving this point on December 3, 1679, the party ascended the St. Joseph, and crossing a portage reached the Kankakee which empties into the Illinois. While La Salle was passing through this region, stopping at several Indian villages, he learned that he was the object of hostility of both Jesuits and other traders and his progress was attended with considerable difficulty. In January, 1680, he built a fortified camp and named it Fort Crèvecœur; it was the first civilized occupation of the present state of Illinois.

Leaving this post in command of Tonty he made a journey of 1000 miles in 65 days to Fort Frontenac in search of supplies. There he found that his agents had plundered the post, and to add to his troubles he now received word that there had been a mutiny among the men left with Tonty, and he immediately went back to his aid. This part of the country of the Illinois had been the scene of serious Indian fighting, the Iroquois having raided the villages which they had burned, leaving desolation behind them. La Salle found Fort Crèvecœur in ruins and no trace of Tonty, so he spent the winter negotiating with the Miamis and other western tribes and even penetrated to the Mississippi River. He then returned to Fort Miami, and in May, 1681, found Tonty at Mackinac. La Salle later returned to Fort Frontenac and then to Canada, put off his creditors and gained the support of the governor for still another expedition.

This time with Tonty, 30 Frenchmen and a band of faithful Indians, in August, 1681, he moved up the lakes and by December, one of his parties under Tonty and Father Membré, was able to cross the Chicago portage to the Illinois, and on the ice, with sledges, descend that stream to its junction with the Mississippi, while he himself traveled by the Kankakee route and joined them so that on February 6, 1682, the expedition embarked. Passing down this great stream, "The Father of Waters", he reached the mouths of the Arkansas and Red Rivers, where in the name of Louis XIV and France, he took formal possession of the country. The party continued until by April 1, they were at the delta of the Mississippi. Here the expedition was divided into three groups and each followed one of the branches flowing into the Gulf of Mexico. Again they reunited and on April 9, 1682, La Salle erected a monument, a cross bearing the arms of France, to signify that in the name of the king he took possession of the river and all the lands drained by it through virtue of discovery, thus giving to France by formal occupation a vast territory. It was the first time the river had been followed from its upper waters to the sea and a definite idea was obtained as to the relation of the central part of the North American continent to the Gulf of Mexico.

This new discovery aroused La Salle's further ambitions and he sought to establish colonies throughout the country. He contemplated a settlement at Starved Rock on the Illinois River, where he built Fort St. Louis, this being a meeting place for the Indians, which proved there was ample opportunity for substantial trade. La Salle's plans now suffered by his inability to receive sufficient supplies from Canada, and particularly from the change of government which had taken place at Quebec. Frontenac had been supplanted by De la Barre, who immediately sought to appropriate the more important of La Salle's privileges and rights. He seized Fort Frontenac and also superseded La Salle at Fort St. Louis by an appointee of his own, demanding the former's immediate return to Quebec.

In obedience to this peremptoriness La Salle returned, but his stay at the capitol was brief and he straightway sailed for France. He was received with no small amount of favor at the court, and by royal command De la Barre was ordered to make restitution, and La Salle was equipped for the largest and what turned out to be the last of his expeditions. With four vessels and 400 men, in command of an officer named Beaujeu, the voyage was made direct to the Gulf of Mexico where it was proposed to found a colony at the mouth of the Mississippi. La Salle was made governor of the territory from the Gulf to Lake Michigan. From the very outset this inauspicious voyage was attended with mishaps, and friction early developed between Beaujeu and La Salle. The Gulf of Mexico was duly reached but unfortunately it was not possible to find the mouth of the Mississippi River. La Salle on his previous trip had made observations on the sun for latitude but he had no longitude and the bays and lagoons were highly deceptive. The hostility between Beaujeu and La Salle developed and the explorer became convinced that the naval officer was endeavoring to wreck the expedition. Not reaching the mouth of the Mississippi they landed at Matagorda Bay, far to the west, after one of the ships had struck a reef, and here a colony was established on the Lavaca River under the charge of Lieutenant Boutell.

Beaujeu returned to France, and La Salle, left alone for the next two years, sought to discover the mouth of the Mississippi and to maintain himself and his party. Returning from a fruitless search in March, 1686, La Salle realized that he was not at the Mississippi River delta and in April of the same year he started for Canada, but was obliged to turn back. The following winter the colony was reduced to 45 men and La Salle and Boutell decided to start for Canada again in January, 1687. The expedition is a continuous story of quarrels, mutiny, etc. Finally La Salle was shot from ambush by some of his own party. Boutell thereupon assumed the leadership and the survivors, and those who were loyal, were able to reach the Arkansas River where Tonty had established a post. This faithful lieutenant in February, 1686, with a band of Indians, had started down the river to effect a junction with La Salle, as arranged, and various trips were made to the Gulf but unfortunately it was not possible to reach La Salle. After the brilliant discoveries and explorations of this great pioneer it was highly unfortunate that the latter part of his life should be marked by disasters, and that he should be able to realize so little of his extraordinary plans and after such herculean efforts.

MERIWETHER LEWIS

Commander of the Famous Lewis and Clark Expedition

MERIWETHER LEWIS, famous as a leader of the Lewis and Clark Expedition which explored the upper reaches of the Missouri River and crossed the Rocky Mountains, was born August 18, 1774, in Charlottesville, Virginia. He came of a well-known Virginia family, being a great nephew of Fielding Lewis, who was a patriot and connected with the Washington and other families. He had inherited moderate wealth and a plantation, but being of an adventurous turn of mind he abandoned farming in 1794, to serve the United States government against the Whisky Rebellion in western Pennsylvania. As a military life appealed to him he entered the regular service in 1795 and was promoted successively from ensign to captain, obtaining the latter rank in 1800. From 1801–1803 he served as President Thomas Jefferson's private secretary, enjoying the friendship and confidence of that statesman whom he had known for many years. At this time the United States was negotiating the Louisiana Purchase and was alive to the political and territorial possibilities of the lands beyond the Mississippi. Accordingly it was proposed to send an exploration party into the great West to look over the field. Captain Lewis in 1803 volunteered for this service and was recommended to Congress by President Jefferson to command the expedition.

He was appointed and chose as his companion Captain William Clark of the regular army who had served against the Indians under General Wayne, and was familiar with western conditions of life and exploration. The party left in the summer of 1803 and included nine young Kentuckians, fourteen soldiers, two Canadian boatmen, an interpreter and hunter, and a negro servant for Captain Clark. Proceeding to the Mississippi River they wintered near St. Louis, and on May 14, 1804, started to ascend the Missouri, passing La Charette, the home of Daniel Boone and the last settlement on the Missouri. They reached the mouth of the Platte River on July 26 and pushed on to the camps of the Mandans and the Minnetarees, in latitude 47° 21′ N. Here they built Fort Mandan and wintered, making their first preparations and visiting the neighboring Indian tribes. In the following spring Lewis sent back 14 men of the party to St. Louis with preliminary reports and collections, and on April 7, 1805, the main expedition again proceeded, reaching the mouth of the Yellowstone on April 26. A month later the Rocky Mountains were in sight, and on July 25 the party reached the junction of three nearly equal streams which they named the Jefferson, Madison and Gallatin.

They selected the Jefferson branch as their route and followed it to its source, traveling through and crossing the Rocky Mountains in August, noticing a "bold creek of cold clear water flowing westward". Once over the Rocky Mountains, on September 22, 1805, they procured horses from the Indians and entered the plains on the western slope, going forward until they could embark in canoes on the Kooskoosky River, a branch of the Columbia. They then followed the main river until on November 7th they gained a glimpse of the Pacific Ocean and soon heard the sound of the surf. The Pacific had been reached, and the object of the expedition achieved. The winter of 1805–6 was passed on the south bank of the Columbia in an intrenched camp, Fort Clatsop, named after the neighboring Indians. As no ships appeared off the coast, on March 23, 1806, the intrepid explorers began to ascend the Columbia on their homeward journey. The route traversed had been mapped and reports had been prepared so that everything was in readiness for the return. Their journey was up the Columbia River until May, when the boats were left and the party rode horseback over the mountains to the Missouri, where they reëmbarked in August, and after an absence of two years and four months they reached St. Louis September 23, having traveled a distance of well over 8000 miles.

Photo Cross & Dimmitt

SACAJAWEA

Statue in City Park, Portland, Oregon, of the Indian woman who, with her new-born babe on her back, guided and was the salvation of the Lewis and Clark Expedition.

The results obtained by the expedition, consisting of geographical data and information regarding the flora, climate and Indian tribes of the region traversed, together with a considerable knowledge of the great resources and possibilities of the unbounded lands on both sides of the Rocky Mountains, well repaid its hardships and cost. This was recognized by Congress by substantial grants of land to the men and their leaders.

Lewis in 1807 was appointed governor of the Louisiana Territory, the northern part of the Louisiana Purchase, which was virtually the region embraced in the subsequent territory of Missouri. He found the country torn by dissension, but with the assistance of Captain Clark, who accompanied him as Indian agent, he was able to restore order by his firmness, impartiality and general administrative ability. In addition to his regular official work he spent considerable time in preparing for publication the records of the great expedition, but these were never finished by him, as his life ended suddenly and mysteriously in October, 1809, in a settler's cabin near Nashville, Tennessee.

The reports that Captain Lewis had made to President Jefferson developed most fully the possibilities of the region through which the expedition had passed, not only on the score of trading, but also as a route to the Pacific where it might be possible to establish connection with ships coming from the Orient. He found that 2575 miles by boat on the Missouri River and its tributaries and a land journey of 340 miles was required to connect the navigable parts of the Missouri and the Columbia. Of this land journey 200 miles were along a good road, but 140 miles were "over tremendous mountains which for 60 miles are covered with eternal snows".

Captain Lewis also realized the full trading possibilities of this region and saw clearly the impending danger to American prestige if it were preëmpted by Canadian companies. Accordingly arrangements were made for American trading and John Jacob Astor of New York immediately organized a company, to enter this territory, and its subsequent operations were conducted to great profit. But most of all the information gained by the Lewis and Clark expediton was valuable in a political sense and gave the American statesmen adequate data on which to conduct negotiations, resulting in the treaties signed in 1815 and later. In short, the Lewis and Clark exploration actually opened up the great Northwest and made possible its incorporation as a substantial and integral part of the United States.

DAVID LIVINGSTONE

The Opener-up of the Dark Continent

DAVID LIVINGSTONE was born at Blantyre, near Glasgow, Scotland, on March 19, 1813, the son of poor parents, who, when he was ten years old, put him to work in a cotton factory. Here he spent ten years, using his spare hours to study Latin and Greek at a night-school.

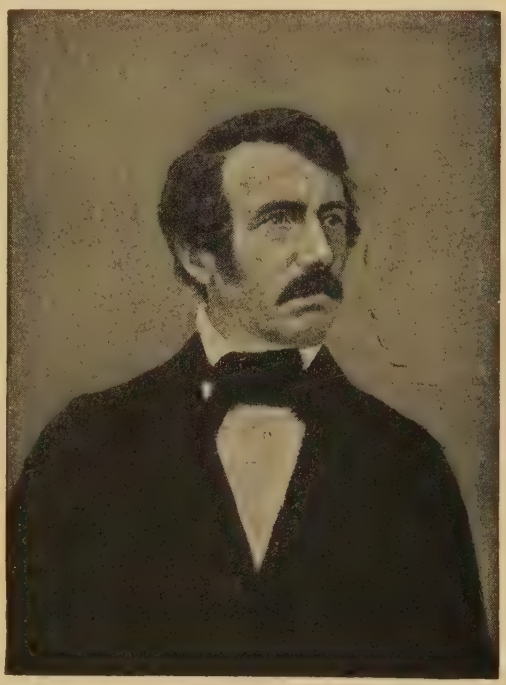
When he was nineteen he became a cotton-spinner, and his extra wages enabled him to put into practice a scheme of studying for the calling of a medical missionary. To this end he toiled at the factory for half the year, and for the rest was a student of medicine at Glasgow University, and attending the lectures of the professor of theology to the Scottish Independents. He was ordained as a medical missionary in 1840 by the London Missionary Society and sent to South Africa. He proceeded inland to Kuruman, traveled far and near in Bechuanaland, then founded a mission in the valley of the Mabotsa.

Africa, in spite of Portuguese, British and Boer settlements, was still, as to the north, a Dark Continent indeed, and it fell to Livingstone to carry the torch of knowledge into its gloomy depths. The transition from missionary to traveler came about in this wise. He found that, wherever the foot of Portuguese or Arab had fallen, the making of slaves was the staple industry. Terrible misery prevailed wherever he turned. He saw that in order to suppress this traffic a definite war by peaceful methods must be prosecuted. The natives must have an organized commerce. For that they must have well-mapped routes by which they themselves could travel in safety to carry their wares to the seaboards of the Atlantic and Pacific, and by which white men could advance into the interior to buy and barter. He set himself to find the paths, to master the languages and to teach Christianity where he learned dialects and routes. To this end, Livingstone, although always a great Christian teacher in Africa, severed his connection with the society by which he had been sent out, to become an unfettered pioneer.

It was with the definite object of finding a transcontinental route that, in 1849, he began his serious travels. Having crossed the vast Kalahari desert, he discovered Lake Ngami, which, then a sheet of water fifty miles in length and from ten to twenty broad, seemed to him, after his desert days, a find of prime importance. Today Ngami is simply a reed-grown swamp except in the rainy season. But the discovery was important in a sense that he did not realize, for it gave a direct aim to his travels, and led him on to the discovery of the Zambesi in the very heart of Africa. Previously this mighty river had been supposed to rise near the coast; yet here it was, in the mysterious depths of this inscrutable land, even in the dry season, a deep swift-flowing river, from three hundred to six hundred yards in breadth, evidence of one certain highway to the eastern seaboard. Without waiting now to explore it, he bore northwest and reached Loanda, on the coast of Portuguese West Africa, in 1854, desperately ill, "a mere ruckle of bones". But he set out upon the return journey the same year, and renewed his exploration of the Zambesi and Kuanza basins.

On the way up he had stopped at Lake Dilolo. He returned thither, and found various tributaries of the Congo flowing northward, with the Zambesi flowing southward. Lake Dilolo sends a feeder to each river system, so linking the Atlantic with the Indian Ocean. Livingstone was led to a correct estimate of the formation of Central Africa, but of course he could not make even a guess as to the details of the great river systems of the continent, and we have him writing, only a few months before his death: "As to this Nile source, I have been kept in perpetual doubt and perplexities. I know too much to be positive. Great Lualaba, or Lualluba, as Manyuema say, may turn out to be the Congo, and the Nile a shorter river after all. The fountains flowing north and south seem in favor of it being the Nile. Great-westing is in favor of the Congo. . . . I am even now not at all cocksure that I have not been following down what may after all be the Congo." Which was exactly what had happened.

Livingstone was the first white man ever to look upon the Victoria Falls. Here the river, 1000 yards broad, leaps 400 feet sheer into a huge fissure in the earth's surface, and, shut in by towering black basaltic cliffs, boils and roars through a channel which has suddenly narrowed to a score or so of yards. Lower down the river were the Portuguese, who have been in occupation almost since Vasco da Gama named the Zambesi the "River of Good Signs", but they had never heard of these falls, the most stupendous in the world.



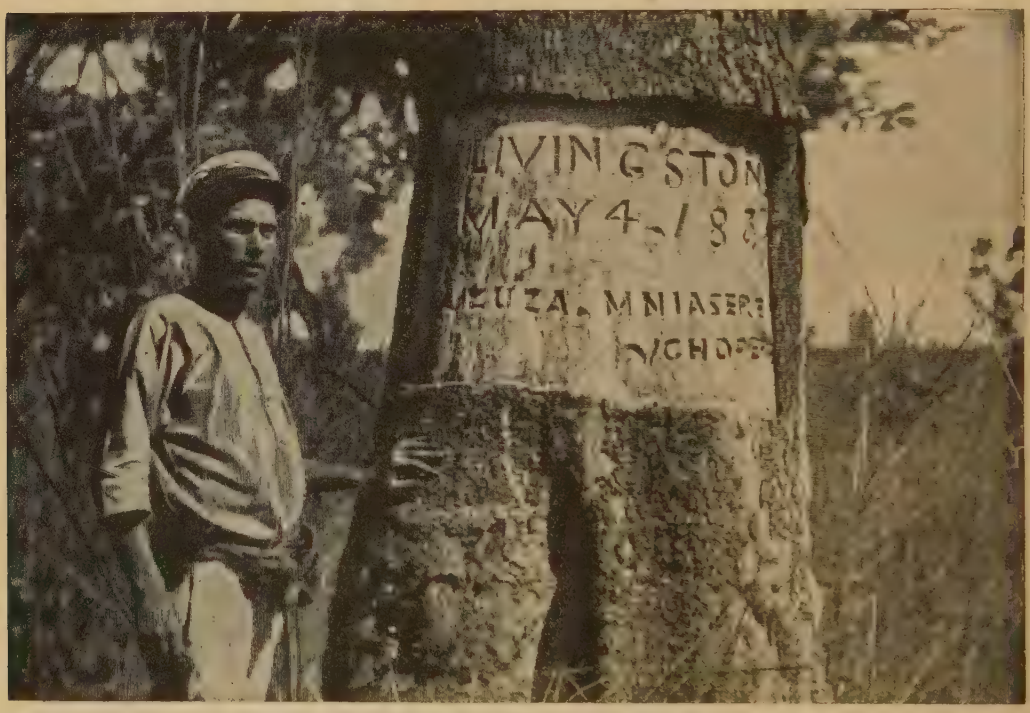
DAVID LIVINGSTONE

Livingstone reached Quilimane, Portuguese East Africa, in May, 1856, having for the first time in history crossed Africa from west to east. He had worked his way, in the course of fifteen years' journeyings, from Cape Town up through Bechuanaland, westward to Loanda, and then eastward to the Indian Ocean. He had already married, and his wife had accompanied him, with their increasing family, on a considerable part of his travels.

Livingstone returned to England, published a book, was fêted and honored, and then set out on a government expedition further to explore the Zambesi.

Resuming his travels in March, 1858, he made careful investigations along the Zambesi, Shiré and Rouma; discovered Lake Nyassa (out of which the Shiré flows) and Lake Shirwa, a lesser body of water 45 miles to the southeast. His devoted wife died during this expedition, and was buried at Shupanga (April, 1862). But his work had to go on. The government recalled the expedition, but at his own cost he explored the northern banks of Nyassa, proceeding by his own little steamer to Bombay, to return thence to England, after an absence of six years.

All his plans miscarried on this expedition. Supplies sent up from Zanzibar were intercepted; those that he deposited were nearly all stolen, and when Stanley, sent out to seek him, came to his aid, he was all but dead. Reinvigorated by the supplies that his rescuer carried, Livingstone, left alone, carried on his work for another year, but his constitution was utterly broken, and he was borne a dying man to Ilala, a village on the south shore of Bangweolo. There on the morning of May 1 (or May 4), 1873, he was found by his attendants, dead.



A MEMORIAL TO DAVID LIVINGSTONE IN THE HEART OF AFRICA

His third and last journey was undertaken in 1866, at the instance of the Royal Geographical Society. Burton, Speke, Grant and Baker had recently added Lakes Tanganyika, Victoria Nyanza and Albert Nyanza to the map, but still the mystery of the Nile's source and of the watershed of Central Africa was not solved. Livingstone was to make another effort. He discovered Lake Bangweolo. Here the Chambese flowing into it, and the Luapula flowing out of it, constitute the headstream of the Congo.

Eleven years before, with the remains of his wife newly committed to the earth, he had written of his own end: "I have often wished that it might be in some far-off, still forest." His wish was fulfilled. His faithful servitors buried his heart beneath a giant tree in Ilala, and, by a journey which will live forever in the annals of heroic travel, bore his body to the coast. It lies now in Westminster Abbey, with a memorial stating: "Brought by faithful hands over land and sea, here rests David Livingstone, missionary, traveler, philanthropist."

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